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ON

WAYNE COUNTY

BY

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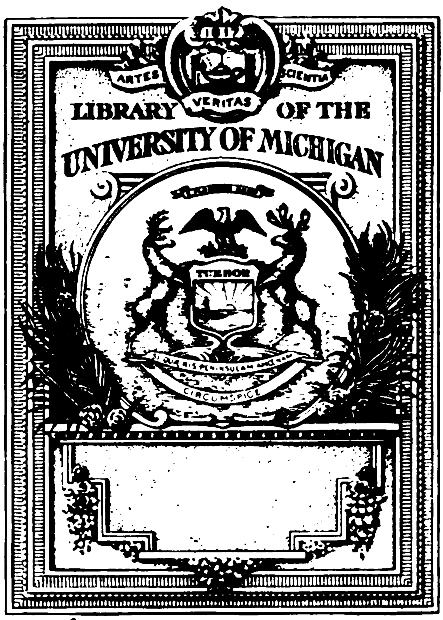

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CHAPTER I.

GEOGRAPHICAL AND HISTORICAL INTRODUCTION.

GEOGRAPHICAL DATA.

Location and size. The county of Wayne, as at present constituted, lies in southeastern Michigan, adjacent to the Province of Ontario, extending along the entire western bank of Detroit River from Milk River Point, Lake St. Clair, to the mouth of Huron River, Lake Erie. To the north, lie Macomb and Oakland counties, to the west, lies Washtenaw, and to the south, Monroe County. The county now covers an area of approximately 616.37 square miles, and, exclusive of the two cities Detroit and Wyandotte, is subdivided into twenty townships. Expressed in latitude and longitude, the county extends from approximately N. Lat. 42°-2′ to 42°-27′ and from W. Long. 82°-52′ to 83°-33′, or through about 25′ of latitude and 41′ of longitude.[1] From the extreme points, the county has a north and south extent of some 29 miles and an east and west extent of 35½ miles; each minute of latitude thus averaging about one and one-seventh miles and, of longitude, about seven-eighths of a mile. The county includes all the islands of Detroit River which lie west of the international boundary, two of which—Belle Isle and Grosse Isle—are of considerable size. The magnetic declination at Belle Isle in 1907 was found to be 1° 29′ *west,* and is increasing at the rate of about 3′ of arc annually. At present writing (1913) it is reported as 1° 45′ W.

Boundaries. No other county in Michigan and, probably, few others in the entire country have had such a varied geographic history as has the county of Wayne. It was originally organized

1. The following is a list of exact determinations of the geographic positions of points along the Detroit River, taken from the reports of the Coast and Geodetic Survey. (Reports for 1902 and 1903, appendix EEE and FFF.)

	Latitude N.			Longitude W.		
Windmill Point light house, Lake St. Clair......	42°	21′	30.389″	82°	55′	48.525″
Belle Isle light house..........................	42	20	24.465	82	57	36.751
City hall flag-staff, Detroit.....................	42	19	52.145	83	02	50.749
Woodward Ave. waiting-room, Det. & Belle Isle Ferry..................................	42	19	33.480	83	02	34.160
Dock upper end Ft. Wayne grounds............	42	17	51.800	83	05	32.300
Grassy Island light house......................	42	13	27.655	83	07	59.556
Mamajudy light house...........................	42	11	30.578	83	08	10.096
Gibraltar light house...........................	42	05	25.900	83	11	14.800
Bois Blanc light house..........................	42	05	12.770	83	07	10.310
Detroit River light house, Lake Erie...........	42	00	02.820	83	08	28.290

Aug. 15, 1796, by Winthrop Sargent, then secretary of the Northwest Territory, the first within the present limits of Michigan and the fifth of those counties originally carved from this Territory.[2] The seat of government was located at Detroit and the county was

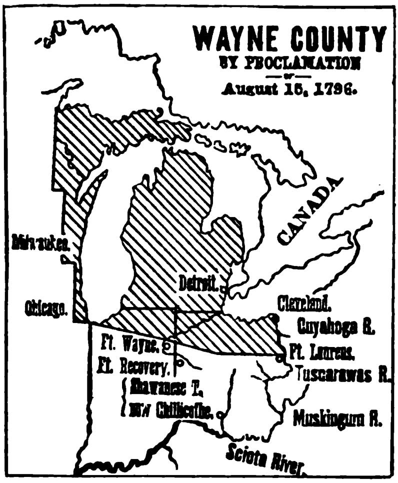

Fig. 1. Wayne county as originally organized by Winthrop Sargent, Secy. of northwest Territory.

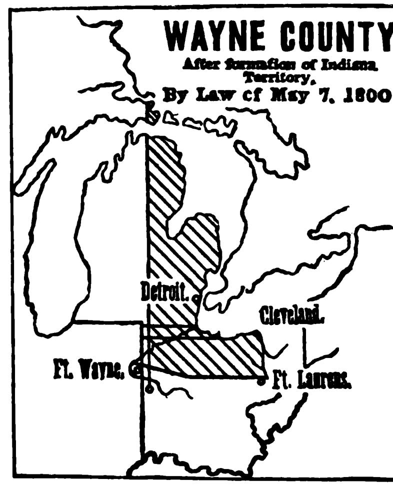

Fig. 2. As reduced after the creation of Indiana Territory.

Fig. 3. After the detachment of the southeast corner in Ohio to help form the county of Trumbull.

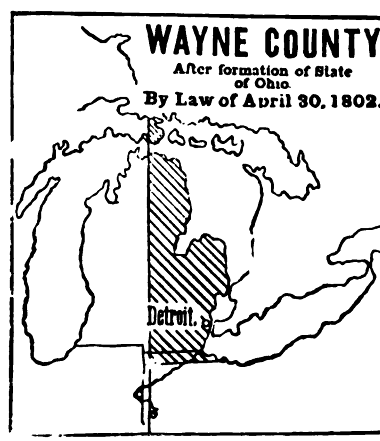

Fig. 4. As reduced at the time that Ohio was admitted to the Union.

named after General Anthony Wayne, who was then in the city, and who had recently achieved such a signal victory over the in-

2. The other counties previously organized were Washington, with seat of government at Marietta, Ohio; Hamilton, with county-seat at Cincinnati, Ohio; St. Clair, seat at Kaskaskia, Illinois; and Knox with seat at Vincennes, Indiana.

dians. As thus organized, the county included practically the whole of Michigan, the northern portion of Ohio to the west of the Cuyahoga River, northern Indiana, northeastern Illinois and a narrow strip of eastern Wisconsin (See fig. 1). The creation of

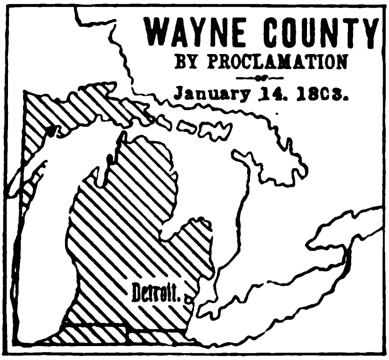

Fig. 5. The boundaries as again defined by Gen. Harrison, then governor of Indiana Territory.

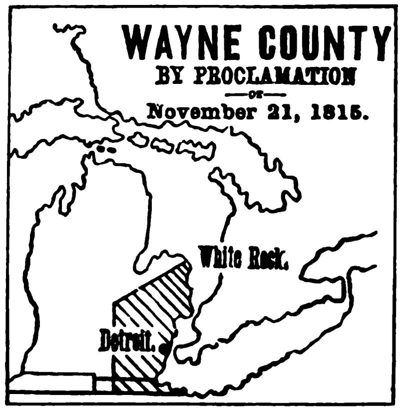

Fig. 6. As reduced by Gov. Cass to include that portion of Michigan Territory to which the Indian title had been extinguished.

Fig. 7. With the district of Mackinac added by Gov. Cass and the separation of Monroe County.

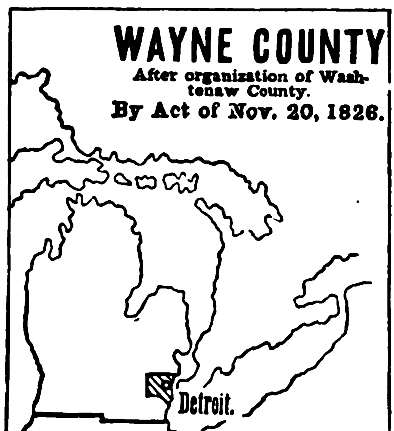

Fig. 8. The final definition of the county by Gov. Cass after the organization of Washtenaw County.

the territories of Indiana and Michigan, the admission of Ohio as a state, and the extinguishing of certain Indian titles demanded various changes in the boundaries of the county and marked reduction in its size, as shown in figures 2, 3, 4, and 6. Oct. 18, 1816, Governor Cass issued a proclamation adding to the county the en-

tirely detached District of Mackinac, as shown in fig. 7, after the county of Monroe had been detached July 14, 1817. With the organization of Macomb County in 1818, the so-called "base line"[3] became the northern boundary of Wayne and, by a proclamation of Governor Cass, the county was assigned its present boundaries Sept. 10th, 1822, but with Washtenaw County temporarily annexed. The latter was organized Nov. 20, 1826, and the present Wayne County definitely established, as shown in fig. 8. Previous to this date, four other neighboring counties had been definitely established and organized:—Monroe (July 14, 1817), Macomb (Jan. 15, 1818), Oakland (Jan. 12, 1819), and St. Clair (Mar. 28, 1820).

The proclamation of Governor Lewis Cass, of Sept. 10, 1822, defining the boundaries of Wayne County reads as follows:

"Beginning in Lake St. Clair, on the boundary line between the United States and the British Province of Upper Canada, at a point due east from the intersection of the base line with Lake St. Clair, and running thence west to the line between the seventh and eighth ranges east of the Principal Meridian; thence with the said line south to the line between the townships numbered four and five, south of the base line; thence with the said line between the said townships four and five to the middle of the said townships four and five to the middle of the River Huron of Lake Erie; thence with the said river, keeping the middle thereof, to its mouth; thence east to the boundary line between the United States and the Province of Upper Canada; thence with the said boundary line to the place of beginning."

County subdivisions. As early as 1798, four townships were created in the then unwieldy county of Wayne:—Detroit, Mackinaw, Sargent, and Hamtramck. To these were added others as the county was narrowed to its present dimensions and increased in population. With the creation of the Board of Supervisors in 1827, the county as now constituted was divided into the following nine townships:—Detroit, Springwells, Hamtramck, Monguagon, Brownstown, Plymouth, Ecorse, Huron, and Bucklin. Two years later, the township of Bucklin was divided into Nankin and Pekin, the latter in 1833, being changed to Redford. By further subdivision, eleven other townships have been organized from the re-

3. This east-west line of reference was surveyed under the direction of the General Land Office, then a branch of the Treasury Department; Edward Tiffin Surveyor General. Its survey through ranges 6, 7, 8, 9, 10, and 11 east of the Michigan Meridian was made in November, 1815, by Alexander Holmes. The line was resurveyed through ranges 9, 10, and 11 in September, 1816, and extended through ranges 12 and 13, east, by Joseph Fletcher, closing on the "west line of private grant No. 656, confirmed to Nicholas Rivan." A resurvey was made through range 7, east, in 1823, by Joseph Wampler and continued through range 5, east, in 1823 and through ranges 4, 3, 2, and 1 in 1829, closing on the Meridian.

mainder, making twenty in all since 1903. These are listed in table I, with statistical data that may prove of interest to the reader. The foreign names were selected in order to avoid the possible duplication of names then in use for postoffices.

The following information relating to the original survey of the townships of Wayne County is supplied by the State Land Office.

T. 1 S., R. VIII E. (Northville and Plymouth).
Township lines by Alexander Holmes, 1815.
Subdivisions by Joseph Wampler, 1815.
T. 1 S., R. IX E. (Livonia).
South and east township lines by Joseph Fletcher, 1816.
North and west township lines by Alexander Holmes, 1815.
North line corrected by Joseph Fletcher, 1819.
Subdivisions by Joseph Fletcher, 1816.
T. 1 S., R. X E. (Redford).
Township lines and subdivisions by Joseph Fletcher, 1816.
T. 1 S., R. XI E. (Greenfield).
Township lines (1816) and subdivisions (1817) by Joseph Fletcher.
T. 1 S., R. XII E. (Hamtramck and part of Gratiot).
Township lines and subdivisions by Joseph Fletcher, 1816.
T. 2 S., R. VIII E. (Canton).
Township lines by Alexander Holmes, 1815.
Subdivisions by Joseph Wampler, 1819.
T. 2 S., R. IX E. (Nankin).
Township lines by Joseph Fletcher and Alexander Holmes, 1815–16.
Subdivisions by Joseph Fletcher, 1816.
T. 2 S., R. X E. (Dearborn).
Township lines and subdivisions by Joseph Fletcher, 1816.
T. 2 S., R. XI E. (Springwells).
Township lines (1816) and subdivisions (1817) by Joseph Fletcher.
Line between public lands and private surveys by Joseph Fletcher, 1822.
T. 3 S., R. VIII E. (Van Buren).
Township lines by Alexander Holmes, 1815.
Subdivisions by Joseph Wampler, 1819.
T. 3 S., R. IX E. (Romulus).
West township line by Alexander Holmes, 1815.
North, east and south township lines by Joseph Fletcher, 1816.
Subdivisions by Joseph Fletcher, 1817.
T. 3 S., R. X E. (Taylor and part of Ecorse).
Township lines by Joseph Fletcher, 1816–17.
Subdivisions by Joseph Fletcher, 1817.
"Mammy Judy" and Grassy Island by H. Brevoort, Jr., 1845.
T. 4 S., R. VIII E. (Sumpter).
Township lines by Alexander Holmes, 1815.
Subdivisions by Joseph Francis, 1819.
Reserve by James H. Mullett, 1843.
T. 4 S., R. IX E. (Huron).
West township line by Alexander Holmes, 1815.
North, east and south township lines by Joseph Fletcher, 1816.
Subdivisions by Joseph Fletcher, 1816.
T. 4 S., R. X E. (Parts of Brownstown and Monguagon).
Township lines and subdivisions by Joseph Fletcher, 1816.
T. 4 S., R. XI E. (Part of Monguagon).
Township lines and subdivisions by Joseph Fletcher, 1817.
T. 5 S., R. X E. (Part of Brownstown).
Township lines (1816) and subdivisions (1817) by Joseph Fletcher.

Population. Starting with Cadillac's company of 50 soldiers and 50 artisans and traders, at the time of the first settlement within the present limits of Wayne County, July 24, 1701, the white population grew very slowly and fluctuated much for 100 years. The settlement depended at first entirely upon the fur trade and agriculture was purely incidental. The United States census of 1810 credited the Civil District of Detroit with a population of 2,227 and Wayne County, as it existed in 1820, two years before its final delimitation, with 3574. Since the final organization of the county its growth by decades is indicated in the following table, based upon the U. S. Census.

TABLE I. GROWTH OF WAYNE COUNTY IN POPULATION, BY DECADES.

Date.	Population.	Percentage of increase.
1830	6,781	....
1840	24,173	256
1850	42,756	77
1860	75,547	77
1870	119,038	58
1880	166,444	40
1890	257,144	54
1900	348,793	36
1910	531,591	52

TABLE II.—STATISTICAL DATA RELATING TO TOWNSHIPS—(NOT INCLUDING CITY OF DETROIT).

Number.	Township.	Tier south.	Range east.	Date of establishment.	Date of original survey.	Origin of name.	Approximate area in sq. mi.	Population in 1900.	Population in 1904.	Population in 1910.
1	Brownstown	4–5	X	1827	1816–1817	From Adam Brown	40.005	2,031	2,034	2,045
2	Canton	2	VIII	1834	1815–1819	City of China	35.935	1,218	1,179	1,113
3	Dearborn	2	X	1833	1816	Gen. Henry Dearborn	34.410	2,752	2,656	2,761
4	Ecorse	2–3	X–XI	1827	1816–1817	From Ecorse or "Bark" River	35.410	6,675	8,219	9,398
5	Gratiot	1	XII–XIII	1903	1816	Col. Charles Gratiot	19.425	1,333	1,326	1,900
6	Greenfield	1	XI	1833	1816–1817	Allusion to appearance of fields	34.782	2,360	2,646	4,995
7	Grosse Point	1–2	XIII	1848	1817	Large point of land	11.310	2,933	3,010	3,579
8	Hamtramck	1	XII	1827	1816	Col. John Francis Hamtramck	16.888	3,078	3,778	7,122
9	Huron	4	IX	1827	1815–1816	Huron River from Indian tribe	35.790	1,978	1,838	1,690
10	Livonia	1	IX	1835	1815–16–19	Probably the province of Russia	35.960	1,460	1,383	1,365
11	Monguagon	4	X–XI	1827	1816–1817	Potowatamie chieftain	23.355	2,387	2,797	3,367
12	Nankin	2	IX	1829	1815–1816	City of China	35.940	3,812	3,857	3,966
13	Northville	1	VIII	1897	1815	Named from village	18.270	2,371	2,226	2,274
14	Plymouth	1	VIII	1827	1815	Probably from Plymouth, Mass.	19.140	2,098	2,264	2,248
15	Redford	1	X	1829	1816	From ford of the "Rouge"	35.680	1,990	1,985	2,176
16	Romulus	3	IX	1835	1815–16–17	Founder of Rome	35.660	1,816	1,741	1,538
17	Springwells	2	XI	1827	1816–1817	From abundance of springs	9.830	13,034	16,660	1,835
18	Sumpter	4	VIII	1840	1815–1819	Gen. Thomas Sumter	37.285	1,495	1,320	1 228
19	Taylor	3	X	1847	1816–1817	Gen. Zachary Taylor	23.825	1,296	1,191	1,238
20	Van Buren	3	VIII	1835	1815–1819	Pres. Martin Van Buren	36.690	1,789	1,701	1,700
	Total	1–5	VIII–XIII				575.590	57,906	63,811	57,538

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20	Van Buren	3	VIII	1835	1815–1819	Pres. Martin Van Buren	36.690	1,789	1,701	1,700
	Total	1–5	VIII-XIII	....	....	....	575.590	57,906	63,811	57,538

TABLE II.—Concluded.

Number.	Township.	List of postoffices in 1913.	Remarks.
1	Brownstown	Flatrock, Rockwood	Gave portion to Monguagon in 1842.
2	Canton	Canton	Derived from Plymouth.
3	Dearborn	Dearborn, Inkster	Reduced from larger Dearborn.
4	Ecorse	Navarre, Ecorse, River Rouge	Reduced to form Taylor in 1847.
5	Gratiot		Derived from Hamtramck and Grosse Point.
6	Greenfield	Highland Park, Howlett	Derived from Springwells.
7	Grosse Point	St. Clair Heights, Cottage Grove, Paye, Grosse Point Farms	Derived from Hamtramck.
8	Hamtramck	Hamtramck, North Detroit, Leesville	Contributed to Detroit, Grosse Point and Gratiot.
9	Huron	New Boston, Waltz, Willow	Reduced to form Sumpter, Van Buren and Romulus, and known as East Huron awhile.
10	Livonia		Derived from Nankin, formerly part of Bucklin.
11	Monguagon	Trenton, Sibley, Grosse Ile	Increased by addition from Brownstown, 1842.
12	Nankin	Wayne, Eloise	Derived from Bucklin and included Livonia.
13	Northville	Northville	Separated from Plymouth.
14	Plymouth	Plymouth	Formerly included Canton and Northville.
15	Redford	Redford, Greenfield	Name in 1833 changed from Pekin, part of Bucklin.
16	Romulus	Romulus	Derived from Huron.
17	Springwells	Springwells	Contributed to Detroit and Greenfield.
18	Sumpter		Derived from Huron and for a time called West Huron.
19	Taylor	Taylor Center, Hand Station	Derived from Ecorse.
20	Van Buren	Denton, Belleville, French Landing.	Derived from Huron.
	Total	36 offices.	

From an inspection of the table, it will be noted that the greatest relative increase in population occurred during the decade when the territory became a state, while the greatest actual increase (182,797) occurred during the last decade 1900 to 1910, it now having approximately 19% of the entire population of the state (2,810,173). This abnormal rate of growth is due, of course, to the very rapid industrial development of the city of Detroit. Although the percentage of increase was also large in the adjacent counties, between 1820 and 1840, owing to the tide of emigration from the East, their growth from decade to decade has been moderate and some of them (Monroe, Oakland and Washtenaw) have at times shown an actual loss. The population of the townships for 1900, 1904 and 1910 is given in Table I. They have suffered, (the loss during the last decade being 6,273) as well as the adjacent counties, because of their proximity to a rapidly growing city. The average density of population throughout the county, outside the two cities of Detroit and Wyandotte, is 100 to the square mile, or about one person to every 6.4 acres. If the hamlets and villages are excluded the strictly rural population would average about 50 to the square mile, or about one individual to each 13 acres.

Although founded in 1701, Detroit was not incorporated as a town until Jan. 18, 1802, and as a city, Sept. 13, 1806. In the meantime, the town had been wiped out, so far as structures were concerned, by the great fire of June 11, 1805, commemorated in the present seal of the city. As so often happens, here was a blessing in disguise as it led to a new plan of streets and parks, furnished a new basis for land titles and a revision of the local government. In 1809 this act of incorporation as a city was repealed and a new charter was not granted the city until Oct. 24, 1815. Its growth in population during the past 100 years is indicated in the following table (U. S. Census):—

TABLE III.—GROWTH OF DETROIT IN POPULATION, BY DECADES.

Date.	Population.	Percentage of increase.
1810	770	....
1820	1,442	87
1830	2,222	54
1840	9,192	314
1850	21,019	129
1860	45,619	117
1870	79,577	74
1880	116,340	46
1890	205,876	77
1900	285,704	39
1910	465,766	63

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1890	205,876	77
1900	285,704	39
1910	465,766	63

The present area of the city is approximately 42 square miles and its average density of population hence is 11,156 to the square mile, attaining a maximum of 38,793 in the 9th ward and a minimum of 17,109 in the 2nd ward. An interesting table showing the geographic development of the city has been prepared by City Engineer R. H. McCormick and is here reproduced.

TABLE IV.—GROWTH OF DETROIT IN AREA.

Dates.	Annexed.	Total area.
1806		0.33 sq. mi.
1815	1.03 sq. mi.	1.36 sq. mi.
1827	1.20 sq. mi.	2.56 sq. mi.
1832	1.61 sq. mi.	4.17 sq. mi.
1836	1.09 sq. mi.	5.26 sq. mi.
1849	0.59 sq. mi.	5.85 sq. mi
1857	6.90 sq. mi.	12.75 sq. mi.
1875	2.25 sq. mi.	15.00 sq. mi.
1879	1.09 sq. mi.	16.09 sq. mi.
1885	6.10 sq. mi.	22.19 sq. mi.
1891	5.95 sq. mi.	28.14 sq. mi.
1894	0.21 sq. mi.	28.35 sq. mi.
1905	0.45 sq. mi.	28.80 sq. mi.
1906	6.90 sq. mi.	35.70 sq. mi.
1907	5.08 sq. mi.	40.78 sq. mi
1912	0.97 sq. mi.	41.75 sq. mi.

The city of Wyandotte was incorporated in 1867, being set off from the township of Ecorse. At the first U. S. Census in 1870, it possessed a population of 2,731, from which it has had a steady growth; 3,631 in 1880, 3,817 in 1890, 5,183 in 1900 and 8,287 in 1910. The list of villages in Wayne County at present writing, with the date of incorporation and population data is given below.

TABLE V.—STATISTICAL DATA RELATIVE TO VILLAGES.

Number.	Village.	Township.	Incorporated.	Population.		
				1900.	1904.	1910.
1	Belleville	Van Buren	1905			486
2	Dearborn	Dearborn	1893	844	820	911
3	Ecorse	Ecorse	1903		741	1,063
4	Ford City	Ecorse	1903		1,372	1,689
5	Grosse Point Farms	Grosse Point	1893	817	615	862
6	Grosse Point Village	Grosse Point	1870	343	417	830
7	Grosse Point Park	Grosse Point	1907			290
8	Grosse Point Shores	Grosse Point	1911			
9	Hamtramck	Hamtramck	1901		1,559	6,559
10	Highland Park	Greenfield	1889	427	612	4,120
11	Northville	Northville	1867	1,755	1,627	1,665
12	Oakwood	Ecorse	1910			781
13	Plymouth	Plymouth	1867	1,474	1,663	1,671
14	Redford	Redford	1907			328
15	River Rouge	Ecorse	1899	1,748	2,474	4,163
16	St. Clair Heights	Grosse Point	1903		545	1,252
17	Trenton	Monguagon	1855	1,167	1,201	1,224
18	Wayne	Nankin	1869	1,361	1,218	1,263

The grounds for the U. S. Fort Wayne, comprising a tract of eighty and one-half acres in the western part of the city of Detroit, was ceded to the general government by an act of the state legislature, approved March 26, 1867. At present writing (March 1910), there is stationed here a garrison of 600 enlisted men and 38 officers.

Railways. With such a concentration of population along Detroit River and for years with the only ferry for heavy traffic at Detroit, it is readily understood why Wayne County is so generously supplied with railway facilities, both steam and electric. Both types of roads radiate from Detroit like a great arterial system, sustaining and supporting its industrial activity and distributing its products to even the remote corners of the earth. Rendered possible and called into existence by such industrial development, these roads, conjointly with the shipping, have had much to do with the remarkable growth and development of the county, enabling it to lead all others in the state in population, wealth and achievement. In the body of this report, it will be shown that the *geology* of the region furnished the necessary basis for this growth, the full appreciation of which fact is not, at first, easily grasped by the reader.

The first railroad charter granted in the Northwest Territory was to the Pontiac and Detroit Railway Company, July 31, 1830, less than a year after Stephenson's successful demonstration in England of the application to railroads of steam power. This line, however, was not constructed and a more liberal charter was granted March 7, 1834, to the Detroit and Pontiac Railroad Company. In the year 1835 some twelve miles of this road were in operation for horse-cars, the first locomotive being employed in the Fall of 1838.[4] This road was opened to Royal Oak, July 21, 1838; to Birmingham, Aug. 16, 1839, and to Pontiac July 4, 1843,[5] its name being subsequently changed to the Detroit, Grand Haven and Milwaukee and now a part of the Grand Trunk System.

What is now known as the main line of the Michigan Central Railroad, passing westward from Detroit to Chicago, was projected in 1830 and chartered June 29, 1832, by the Territorial Council as the Detroit and St. Joseph Railroad. Started first as a private enterprise the road was purchased by the state in May, 1837, and the name changed to that by which it has since been known. It was opened to Ypsilanti, Feb. 3, 1838; to Ann Arbor, Oct. 17,

4. The Semi-Centennial of the Admission of the State of Michigan into the Union. Address "The Railroads of Michigan" by Maj. W. C. Ransom, p. 183.
5. Farmer's History of Detroit and Michigan, p. 893.

of writing (December, 1911) there are 260 passenger cars and 40 express cars daily over these various electric lines.

River traffic. Owing to its location relative to the river and its splendid harbor facilities Detroit has become an important lake port. From data supplied by the Marine Clerk, of the U. S. Customs Office, the port of Detroit, from July 1, 1910 to July 1, 1911, shows 5,815 vessel entries and 5,705 clearances. The boats enrolled and licensed at Detroit number 250, with an average tonnage of 716. Between New Baltimore and Monroe, it is estimated that there are 3,000 motor boats and 500 small sailing vessels. Detroit River, however, is one of the great avenues of commerce of the world, exceeding that world's great thorough-fare, the Suez Canal. In 1910 there were 33,638 passages reported, with a net registered tonnage of 58,821,282 tons. The estimated quantity of freight carried was 73,526,602 tons, of an estimated value of $771,294,055. The great bulk of this trade consists of iron, copper and grains, south bound and coal north bound.

HISTORICAL DATA.

Mound Builders. The earliest known human residents of southeastern Michigan were apparently identical with, or closely related to, that industrious race of people to whom the name "Mound Builders" has been applied. This name, however, is unfortunate since it fails to distinguish them from the inferior races with which they had little in common. Being an agricultural people and relying almost entirely upon the cultivated products of the soil, they seem to have mastered the art of spinning and weaving, they manufactured pottery and a superior grade of stone weapons, utensils and ornaments. Not satisfied with the use of stone alone, they opened shallow pits in the Lake Superior copper district and systematically mined the red metal, both on the main land and upon Isle Royale. This copper was simply beaten into form and never moulded while in molten condition, so that these people can not be regarded as properly in the "age of metal".[6] Dependent directly upon the soil of a given region for their sustenance it was necessary for them to retain possession of the same, at all hazards, and elaborate and skillfully constructed fortifications were erected; connected often by a series of mounds as signal stations.

6. In the sacrificial fires of the Mound Builders copper objects are found to have been melted and it seems most probable that these people were aware of the fusibility of this metal in moderate heat. Had they had possession of *tin* articles at the same time these two metals would have formed an alloy and the superiority of bronze, over either copper or tin, would very naturally have been discovered. The moulding of the molten alloy would have been but an easy step, thus placing these people upon a much higher plane of culture than that usually acknowledged for them.

The Pere Marquette System maintains a line leading northwestward from Detroit, through Plymouth, Howell and Lansing, connecting at Plymouth with the main line from Toledo for Saginaw and Ludington. Those portions in the vicinity of Wayne County were completed in 1871. A line operated by this same company extends southeastward from Windsor to Leamington, Ontario. In addition to these ten lines of railroads, included in the Michigan Central, Grand Trunk and Pere Marquette systems, four other separate lines enter Detroit:—the Canadian Pacific from the east, the Lake Shore from Toledo, the Wabash and Detroit, Toledo and Ironton railways from the southwest. The "Big Four" cars from the south enter the city over the Michigan Central line; the Cincinnati, Hamilton and Dayton cars over the Pere Marquette and the N. Y. Central trains use the Michigan Central tracks between Buffalo and Chicago. It is estimated that 76 passenger and 99 freight trains enter and leave the city of Detroit daily (December, 1911; Detroit Board of Commerce).

During the decade 1890 to 1900, there was a rapid development of electric lines, centering in Detroit and crossing the county in every direction, paralleling most of the steam lines and competing with them in passenger and light freight business. These lines have had a very marked influence in establishing business and social relations between the city and surrounding country. Most of them, constructed as independent lines, have come under the control of the "Detroit United Railway" and are now operated as a single system. The list of these lines with the dates at which they began operation is here given, the data being supplied by the railway itself.

TABLE VI.—INTERURBAN LINES COMMUNICATING WITH DETROIT.

1	Wyandotte division	1892
2	Detroit, Monroe and Toledo	1903
3	Detroit, Jackson and Chicago:	
	Ann Arbor and Ypsilanti	1890
	Ypsilanti to Detroit	1897
	Ypsilanti to Saline	1899
	Ann Arbor to Jackson	1901
4	Orchard Lake division—about	1897
5	Pontiac division	1895
6	Flint division	1898–9
7	Rapid Ry. System to Mt. Clemens	1894
	to Port Huron	1899
8	Shore Line to Mt. Clemens	1897
9	Sandwich, Windsor and Amherstburg	1902

April 4th, 1911, the Michigan United Railway secured entrance into Detroit, using the tracks of the Detroit United Railway from Jackson eastward. This arrangement gave through service, without change of cars as far as Kalamazoo and Lansing. At the time

archaeologists who have noted the state of preservation of the mound skeletons. The Toltec record states that their new country (Mexico) was reached partly by land and partly by sea, (Gulf of Mexico?) and we may readily believe that people who could cross Lake Superior from the main land to Isle Royale would be capable of this feat of navigation.

A tradition, said to be current amongst both the Algonquin and Iroquois nations, and hence all the more reliable, is of interest in this connection because it may be an echo of the above great event. According to this tradition, these two hostile nations once formed an alliance against a formidable enemy, known to them as the "Alligewi", who lived in the region of the Ohio. After a warfare extending over a period of about one hundred years, these Alligewi were defeated and driven southward.[9] We may seek confirmatory evidence of the above accounts in a study of the remains found in and about the fortifications, since the Mound Builders and their Indian enemies were ethnologically distinct. The Toltecs and their relatives are known to have been characterized by the type of head known as *short*, or "brachycephalic"; while the Algonquins, and to a less extent, the Iroquois, possessed the *long*, or "dolicocephalic" type of head. A very extensive collection of such osteological material was made in Ohio by Warren K. Moorehead and described for him by Dr. H. T. Cresson.[10] The predominant type of skull from the mounds and fortifications is of the short kind. At Fort Ancient, a very extensive work on Little Miami River, the author states "the struggle seems to have been a bitter one * * * *. The longheads were evidently the attacking people, who besieged the earthwork and were buried apart outside of its walls under the stone heaps." Further eastward mounds were found in which, although the short type of cranium greatly predominated there was a mingling of those of the long type, as though the lower race had been partially absorbed or enslaved.

Michigan seems to have been upon the northern outskirts of the Mound Builders' domain and the evidences of their occupancy are relatively meager in the southeastern portion of the state. None are known in Monroe County although low mounds and other structures have probably often been obliterated by the plow. In Wayne County a number of mounds and, at least, one small enclosure were constructed in the vicinity of Detroit River, between Ft. Wayne and River Rouge.

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9. The Iroquois Book of Rites. Hale: Library of Aboriginal American Literature, edited by Brinton, p. 11.
10. Primitive Man in Ohio, Moorehead: Chap. XVII, p. 204.

The enclosure was of oval form, about 250 by 350 feet, surrounded by a low embankment and located on a tract of firm land surrounded by a morass. It was probably prepared as a place of retreat in case of attack. The largest and most interesting of the mounds is located near the mouth of River Rouge, at Delray. This is believed to have been originally 700 to 800 feet long, 400 feet wide and possibly 40 feet in height; not all of which, however, was artificial. The top of the mound gave a commanding view of the river and may have originally carried some form of structure, long since disappeared. Some forty years ago these earth works were made the subject of study by Messrs. Henry Gillman and Bela Hubbard, both of Detroit, to the writings of whom the reader interested is referred for details.[11] The so-called "Prairie Mound," SW. corner of Sec. 4, Hamtramck township, is simply a crescent-shaped sand dune, some 9 to 10 feet high and about 500 feet in length. Upon this William A. Ennis built a house and barn about the year 1865 and came across bones associated with Indian relics,—but whether of the Mound Builder type or not is not known.

The red Indians. History opens with various tribes of the Algonquin and Iroquois nations in possession of the St. Lawrence and the region about the Great Lakes. Of the former nation, the Ottawas, Chippewas and Potawatomi claimed southeastern Michigan as their hunting ground and the site of Detroit had long been occupied by a permanent village known as "Yondotiga", or "Great Village". When Cartier, in 1535, explored the St. Lawrence he found along both banks, in the vicinity of the present sites of Quebec and Montreal, a tribe of Iroquoian stock now known to have been the Hurons, or Wyandots. They were then at war with the New York Iroquois and by the time Champlain arrived in 1603 they had apparently been defeated, their villages were deserted and they had migrated to that restricted territory at the southeastern extremity of Georgian Bay, between it and Lake Simcoe. Here they were visited by Champlain in 1615 and their number variously estimated between 20,000 to 30,000. Even at this distance, however, and in spite of their numbers, they were not safe from their New York enemies, who had procured fire arms from the Dutch, and who pursued them with relentless persistency. The destruction of their fortified villages began in 1647, was completed in

11. "The Mound Builders and Platycnemism in Michigan," Gillman: Smithsonian Report for 1873, p. 364. "The Mound-Builders of Michigan," Gillman: Read before the Detroit Scientific Association, May, 1874. Michigan Pioneer Collections, Vol. II, p. 40 and Vol. III, p. 202. "Ancient Men of the Great Lakes," Gillman: American Association for the Advancement of Science, 1875, p. 316. See also report for 1876, p. 300 and p. 311. Memorials of a Half Century, Hubbard, 1888, p. 201.

1649 and large numbers perished or were led into captivity.[12] The demoralized and disorganized remnant of the Hurons was scattered and sought the protection of friendly tribes; the one group in which we are here interested going to the "Tionontati," who dwelt to the westward of the Huron country. Still pursued, however, they retreated to Christian Island, in Georgian Bay; thence to Mackinac, Manitoulin Island, secured an asylum among the Potawatomi in Wisconsin for a short time and then moved westward into Illinois. But here encountering the hostility of the Sioux nation they returned to Michigan by way of the south shore of Lake Superior and about 1670 built a palisaded village at St. Ignace. Subsequently from here a portion of them moved to Detroit River and to Sandusky, Ohio, and became known as the Wyandots. Although not numerous, they became influential and claimed and exercised the right to light the council fire at all intertribal councils, which fire was located in Brownstown township, near the Huron. The remnants of the tribe about Detroit River were gathered into reservations by the United States and Canadian governments, with the final sale of which the Indians have been gradually absorbed by the French and English population. The last of the chiefs in this region were Joseph White and Alexander Clark. The Ohio band ceded their lands in the county which bears their name (Wyandot) in 1842 and repurchased the next year in Indian Territory at the junction of the Missouri and Kansas rivers. Tribal relations were dissolved in 1855 and their land allotted in severalty but again resumed by a portion of the tribe who purchased a small tract from their old enemies the Senecas and still reside in the northeastern corner of the territory.

Both the Iroquois and the Algonquins constructed settled villages, generally protected by strong palisades and the former are known to have thrown up mounds of earth. Both nations cultivated maize and other food plants, more or less systematically, which supplemented the fruits of the chase. They wove mats and baskets but were not known to have produced cloth and their pottery and stone implements were crude, when compared with that of the Mound Builders. They were plainly in a lower stage of culture and, separated from the latter quite sharply by the cranial differences above noted. The practice of constructing a fortified village and the cultivation of the soil to such a marked

12. For a graphic description see "The Jesuits in North America in the Seventeenth Century" by Parkman: Chapters XXVI and XXVII. See also "The Downfall of the Huron Nation," C. C. James: Transactions of the Royal Society of Canada, second series, vol. XII, section ii, 1906, p. 311.

extent is not to be expected amongst a hunting and fishing people, the pastoral stage usually intervening. It is a matter of some surprise also that they should have relied so fully upon the maize, which they must have procured from Mexico, or still further south, where the supposed ancestral plant (teosinte) is native.[13] If we grant the southwestern origin of the Mound Builders these anomalies are readily explained;—this short-headed, but more cultured race, brought the maize with them, this being their staple food. From them the ancestral Algonquins and Iroquois learned of its great value and its method of culture; learned of the advantage of fortification and got an object lesson in mound construction for religious purposes. The knowledge and manual skill necessary for the production of cloth, high grade pottery and stone utensils could not be so easily stolen. Had the Indian descended from the Mound Builders, skill in these arts very probably would not only not have been lost but would have been improved upon.[14] If we thus reject this origin for our eastern aborigines, then we have left nothing but conjecture and speculation; one view being that they reached America from northeastern Asia and the other that they navigated the Atlantic and crossed directly from Europe.[15]

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13. Sargent, Corn Plants, their Uses and Ways of Life, 1899, p. 93. Harshberger, Maize; A Botanical and Economic Study, 1893. See also Cyclopedia of American Agriculture, vol. II, 1911, p. 399. Fiske, The Discovery of America, vol. i, 1892, p. 27. Fiske points out the great ease with which maize may be grown and harvested and that its yield per acre is greater than that of any other cereal.

14. Without all the evidence which we now have before us, a number of eminent authorities have contended that the Mound Builders were the ancestors of the Indians found in possession of the region. (Brinton, Carr, Nadaillac, Thomas, Moorehead, etc.) That they were racially distinct has been maintained by Bancroft, Wilson, Foster, Morgan and McLean. Maj. J. W. Powell held that, although many tribes of Indians actually constructed mounds, none of them could be accredited with having made the extensive works of the Ohio and Mississippi valleys. This view was also shared by Prof. T. W. Putnam and now appears most tenable.

15. There has recently been brought to light an extensive collection of articles which would seem to indicate that another and totally different race of people had temporary possession of this region. Chiefly through the investigations of Daniel E. Soper, Ex-Secretary of the State of Michigan; Rev. James Savage, pastor of Most Holy Trinity Church and John A. Russell, Vice-President of the Home Telephone Company and Ex-Secretary of the Detroit Chamber of Commerce, many low mounds in the vicinity of Highland Park and River Rouge have been opened. The mounds are described as being ellipsoidal in form, 10 to 30 feet in length, the longer axes placed generally east and west and about twice the length of the shorter, and one and one-half to two feet high. Upon the slightly hollowed surface of the earth a fire was built, the articles deposited and loose soil heaped up to form the tumulus. The articles found and now in the possession of the three above named citizens of Detroit consist of records in undecipherable hieroglyphic upon copper, slate and clay; pictorial records upon the same materials, mainly of Old Testament stories; caskets and urns of clay; articles of warfare, domestic use and adornment, made of copper and stone. They purport to be Assyro-Babylonian, or Egyptian, and to depict a conflict between them and the American Indian. The authenticity of these relics has been very strenuously disputed by expert authorities who have either examined the articles or photographic reproductions of the same. Such views have been taken by Dir. A. H. Griffith, formerly of the Detroit Museum of Art; Prof. F. H. Kelsey, University of Michigan; Dr. Morris Jastrow, Jr., University of Pennsylvania; Prof. Frederick Starr, University of Chicago, and Dr. James E. Talmadge, Curator of Deseret Museum, Salt Lake City. Those interested in the discussion, pro and con, may be referred to the literature cited below. The writer cannot doubt the sincerity of the men who are making the finds and believes that a careful and comparative study will certainly prove the fraudulent character of the material, if such it is. The modern manufacture of such material is attended with such difficulty that only a genius and scholar could hope to make a success of it and we shall ultimately know the truth. Dr. Talmadge made a trip from Salt Lake City to Detroit especially to investigate the finds and succeeded in excavating some of the artifacts himself, but under circumstances that did not convince him of their genuineness. Accepted as real they indicate that a race of Caucasians from southwestern Asia familiar with the book of Genesis wandered into this section of Michigan, where they came into conflict with an inferior race apparently the American Indians, who kept them moving so continuously that no time was found for the erection of enduring structures. Their records were made in pictographs and in characters

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16. Memorials of a Half Century, Hubbard, p. 159.
17. Read before the Society of Colonial Wars of the State of Mich., Jan., 1902.
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The "Michigan Relics," a Story of Forgery and Deception, Dr. James E. Talmage: Deseret Museum Bulletin, New Series No. 2, 1911.

there met LaSalle and his party who were just finishing the "Griffon," the first sailing vessel upon the upper lakes. Bound for Green Bay and fated to never return, this vessel of some sixty tons burden, fantastically built and decorated, entered Detroit River on Aug. 11, 1679, and reached Lake St. Clair the following day. The journalist of the expedition was Father Louis Hennepin, a Recollect priest, who was most surprised and pleased at the abundance and variety of the game and vegetation. Full of enthusiasm at the prospect he wrote:—"The Country between thofe two Lakes is very well fituated, and the Soil very fertile. The Banks of the Straight are vaft Meadows, and the Profpect is terminated with fome Hills covered with Vineyards, Trees bearing good Fruit, Groves and Forests, fo well difpos'd, that one would think Nature alone could not have made, without the Help of Art, fo charming a Profpect. That Country is ftock'd with Stags, Wild-Goats, and Bears, which are good for Food, and not fierce as in other Countries; fome think they are better than our Pork. Turkey-Cocks and Swans are there alfo very common; and our Men brought feveral other Beasts and Birds, whofe Names are unknown to us, but they are extraordinary relifhing. The Forefts are chiefly made up of Walnut-trees, Chefnut-trees, Plum-trees and Pear-trees loaded with their own Fruit and Vines. There is alfo abundance of Timber fit for Building; fo that thofe who fhall be fo happy as to inhabit that Noble Country, cannot but remember with Gratitude thofe who have difcover'd the way, by venturing to fail upon an unknown Lake for above one hundred Leagues."[19] So delighted was the priest with the region that he urged La Salle to establish a settlement here, but the latter had more ambitious plans and the expedition proceeded on its way.

The first attempt at white settlement in southern Michigan was made by Cadillac in 1701, the site of Detroit being selected because of the higher ground near the river and because it apparently held the key to the navigation of the upper lakes, and consequently to the fur trade of the northwest. Cadillac presented his plans in person to the colonial minister Count Pontchartrain, received the approval of Louis XIV and by way of Ottawa River and Lake Huron reached the site of Detroit, July 24, 1701; landing with fifty soldiers and fifty artisans. A stockade was at once erected, a chapel, magazine, store houses and dwellings and that autumn the first crop of wheat was sown. Owing to political intrigues,

19. "A new Discovery of a Vast Country in America," by Father Louis Hennepin. Reprinted from London Edition of 1698, by Twaites, Vol. I, 1903, p. 109.

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Some Archeological Forgeries from Michigan, Prof. F. W. Kelsey: The American Anthropologist, vol. X, 1908, p. 48.
The "Michigan Relics," a Story of Forgery and Deception, Dr. James E. Talmage: Deseret Museum Bulletin, New Series No. 2, 1911.

there met LaSalle and his party who were just finishing the "Griffon," the first sailing vessel upon the upper lakes. Bound for Green Bay and fated to never return, this vessel of some sixty tons burden, fantastically built and decorated, entered Detroit River on Aug. 11, 1679, and reached Lake St. Clair the following day. The journalist of the expedition was Father Louis Hennepin, a Recollect priest, who was most surprised and pleased at the abundance and variety of the game and vegetation. Full of enthusiasm at the prospect he wrote:—"The Country between thofe two Lakes is very well fituated, and the Soil very fertile. The Banks of the Straight are vaft Meadows, and the Profpect is terminated with fome Hills covered with Vineyards, Trees bearing good Fruit, Groves and Forests, fo well difpos'd, that one would think Nature alone could not have made, without the Help of Art, fo charming a Profpect. That Country is ftock'd with Stags, Wild-Goats, and Bears, which are good for Food, and not fierce as in other Countries; fome think they are better than our Pork. Turkey-Cocks and Swans are there alfo very common; and our Men brought feveral other Beasts and Birds, whofe Names are unknown to us, but they are extraordinary relifhing. The Forefts are chiefly made up of Walnut-trees, Chefnut-trees, Plum-trees and Pear-trees loaded with their own Fruit and Vines. There is alfo abundance of Timber fit for Building; fo that thofe who fhall be fo happy as to inhabit that Noble Country, cannot but remember with Gratitude thofe who have difcover'd the way, by venturing to fail upon an unknown Lake for above one hundred Leagues."[19] So delighted was the priest with the region that he urged La Salle to establish a settlement here, but the latter had more ambitious plans and the expedition proceeded on its way.

The first attempt at white settlement in southern Michigan was made by Cadillac in 1701, the site of Detroit being selected because of the higher ground near the river and because it apparently held the key to the navigation of the upper lakes, and consequently to the fur trade of the northwest. Cadillac presented his plans in person to the colonial minister Count Pontchartrain, received the approval of Louis XIV and by way of Ottawa River and Lake Huron reached the site of Detroit, July 24, 1701; landing with fifty soldiers and fifty artisans. A stockade was at once erected, a chapel, magazine, store houses and dwellings and that autumn the first crop of wheat was sown. Owing to political intrigues,

19. "A new Discovery of a Vast Country in America," by Father Louis Hennepin. Reprinted from London Edition of 1698, by Twaites, Vol. I, 1903, p. 109.

due to the hostility of the Jesuits and jealousy of traders, combined with the ferocity of certain northern and western Indian tribes, the settlement barely held its own for a half century. The policy of Cadillac had been to group the various tribes of friendly Indians about the fort, in order to better control them and at the same time secure mutual support. The Indian allies rendered invaluable assistance at critical times in the history of the infant settlement, until through jealousies, dissensions arose and their support was withdrawn. Inter-marriage between the French and Indians was encouraged at first and is said to have been common. During the French and Indian War, between them and the English and their colonists, both settlers and troops were concentrated at Detroit. With the conquest of Canada by the English, the fort was surrendered to them by the French, Nov. 29, 1760.

English occupation. Friendly with the French for a century and a half, the Hurons and various Algonquin tribes were not pleased to see the English, who had made allies of their Iroquois enemies come into possession of the various western forts. Within less than two years Pontiac, a bold and crafty Ottawa chief, had laid the plans of his great conspiracy, which contemplated the simultaneous destruction of all the posts west of the Allegheny Mountains. Detroit being regarded as the most important one of all received Pontiac's personal attention and undoubtedly would have fallen but for the timely warning of a French maiden Angelique Cuillière (May 1763). The posts of St. Joseph and Mackinac fell easy victims to the treachery of the Indians.[20] For over two years, they continued to harrass the settlement but with the arrival of Col. Bradstreet, Aug. 26, 1764, with an army of 1,200 troops and 300 Iroquois, peace was soon declared and the English experienced but little further trouble from the Indians. During the War of the Revolution, they were the allies of the British and every possible encouragement given them to bring in prisoners or scalps. One of the best known of these prisoners was the noted scout and Indian fighter, Simon Kenton, the friend of Daniel Boone, who made his escape from the fort and cherished to the last the most bitter hatred of the Indians. The close of the war between England and the States, however, did not bring peace to the western settlements owing to prolonged dispute over the boundaries. The English and their Indian allies claimed the Ohio as their boundary and united their forces in order to hold the country to the north and west. The crushing defeats of Generals Harmer and St. Clair followed,

20. Farmer's History of Detroit and Michigan, Chap. 38. Also Journal of Pontiac's Conspiracy; translated by Ford, published by C. M. Burton, Detroit, 1912.

when Gen. Anthony Wayne ("Mad Anthony" of his troops, "Black-snake" of the Indians) took the field and gained such a signal victory over the Indians at the Rapids of the Maumee, that they were glad to accept terms of peace. Detroit was evacuated by the British on the 11th of July, 1796, and was garrisoned by a detachment of troops from Wayne's army. During the war of 1812, following Hull's disgraceful surrender of the city, the British flag again floated over the fort from Aug. 16, 1812, to Sept. 28, 1813. The return of the Stars and Stripes marked the fifth time that the flag had been changed over the settlement. The hostility of the Indians against the Americans led to further outbreaks which started in 1806 and continued until the defeat of Proctor by Harrison at the battle of the Thames. Tecumseh, a Shawanese warrior, who seemed the reincarnation of old Pontiac in treachery and aggressiveness, with the help of his twin brother "The Prophet", who claimed supernatural powers, endeavored to unite all the Indians of the northwest against the Americans. During the War of 1812 they were the allies of the British, Tecumseh holding the rank of a brigadier-general; but the victories of Harrison on land and Perry on the lake brought peace again to the region.

Previous geological work.[21] No systematic geological work was attempted in this portion of the state so long as Michigan remained a territory, but immediately upon its admission to the union, the legislature deemed it wise to organize a geological survey. The act of the legislature was approved by Gov. Mason, Feb. 23, 1837, and Dr. Douglass Houghton was appointed director of the survey. The year following the work of the survey was extended and a geological board organized by Dr. Houghton with departments of geology, mineralogy, topography, zoölogy and botany. The work in geology and mineralogy was assigned to the assistant geologists Bela Hubbard and Columbus C. Douglas; the topography to S. W. Higgins; the zoölogy to Dr. Abram Sager and the botany to Dr. John Wright. The season of 1838 saw much activity amongst these pioneer workers, most of it expended in the southeastern portion of the state, and early in the year following reports from each were ready and were included in the Second Annual Report of the State Geologist.[22] The survey of Monroe and Wayne counties had been assigned to Hubbard and were here reported upon, the Wayne report comprising some eighteen pages

21. An account of the organization and work of the various geological surveys of the state will be found in the writer's Report upon Monroe County, which may be secured by making application to the State Geologist.
22. Senate Document No. 12, pp. 264–391, session of 1839. Also published as House Document No. 23, pp. 380–507.

and covering the following subjects:—Topographical features; soil and agricultural character; boulders, marshes or wet prairies; encroachments of the river and lakes; clay; limerock; brine springs; water, wells and springs and roads. Considering the difficulties in the way of geological exploration at this early day, this work of Hubbard and his shrewd interpretations command admiration. The map of the county, prepared by Higgins, appeared a year later in the Third Annual Report,[23] dated Feb. 3, 1840. The science of geology was still too much in its infancy and too little could then be learned of the nature of the underlying rock layers to attempt any correlations or the construction of a geological map. In the Third Annual Report, Hubbard refers the limestones of Wayne and Monroe counties to the so-called "Cliff limestones" of Indiana and recognized an eastern and western division, distinguished lithologically and palaeontologically and separated by the silicious beds which we now term the Sylvania formation. They were properly stated, further, to underlie the "black strata" which are now referred to as the Antrim shale. In the Fourth Annual Report of the State Geologist, under date of Jan. 24, 1841, Hubbard gives a geological resumé of the formations studied by him. The "Limestones of Lake Erie" included not only the true limestones of Wayne and Monroe counties but also the dolomites and sand rock lying beneath. Above this limestone series was placed the "Black, bituminous, aluminous slate", just referred to, and still higher a "Soft, coarse grained sandstone". The boulder clay mantling these rock formations was identified as "Tertiary", upon which rested the "ancient alluvions" (glacial lacustrine deposits) and the "recent alluvions" (marl, peat and bog ore.)

During the subsequent surveys of Dr. Alexander Winchell and Dr. Carl Rominger, no especial attention was given to Wayne County, except a more or less casual examination of the limestones and dolomites exposed about Detroit River. Both investigators, however, made a careful study of these same beds as seen in outcrop in Monroe County and upon these studies based their geological maps of this corner of Michigan. In his Biennial Report, published in 1861, Winchell includes all of these beds under the "Upper Helderberg" (p. 140), although he recognized important lithological differences in the strata. In his geological map of the lower peninsula of Michigan, the first to be prepared and published,

23. Senate Document No. 7, Vol. II, pp. 66–153; House Document No. 27, Vol. II, pp. 206–293; also separately No. 8, pp. 1–120.

1873 in Walling's Atlas, he still grouped the limestones and dolomites together geologically as the "Corniferous." This included the beds of the Sibley quarry, rich in lime carbonate and Devonian fossils, and the dolomites of Grosse Isle, Stony Island and Gibraltar, poor in lime carbonate and Silurian fossils. Crossing Wayne County from northeast to southwest there was represented, just to the west of the Corniferous, a narrow belt of "Little Traverse", regarded as of Hamilton age and extending northward as far as Delray. Parallel with this, across the center of the county, there is next represented a belt of the "Huron Group," some 10 to 15 miles in breadth and regarded as the geological equivalent of the Genesee, Portage and Chemung formations of the New York series. The northwestern corner of the county is covered by the "Marshall sandstone", regarded then as the lowest member of the Carboniferous. This map by Winchell is of special interest since it is the first attempt to depict the geology of the county, but is based upon data obtained almost entirely outside. The occurrence of the Waterlime division of the Lower Helderberg in Monroe County was noted by Winchell in 1870, but was not considered as extending into Wayne.

A study of the Sibley strata, with their characteristic fossils, led Rominger to correlate these beds with those on the Macon and Raisin in the northwestern part of Monroe County and to identify them with the Upper Helderberg of New York. He made the error, however, of extending them downward to the Sylvania sandstone, which he greatly underestimated in thickness, and, following the Ohio geologists, correlated with the Oriskany. The dolomites below the Sylvania, he properly referred to the Lower Helderberg, now described as the Lower Monroe Series. In his map (1876), the geology of southeastern Michigan is much simplified by the union of the Upper and Lower Helderberg under "Helderberg" and the omission of the Sylvania and Hamilton formations, the latter not believed to be present in this portion of the state. In Wayne County alone, we have represented the upper division of the Helderberg, comprising the southeastern corner; the Waverly sandstones crossing the northwestern corner and regarded as of Devonian age, while between the two, there extends the broad belt of "Black Shale", the representative of the Genesee shale of the New York Series.

During the administrations of the state geologists, Charles E. Wright (1885-1888) and Dr. M. E. Wadsworth (1888-1893), numerous well records were collected from which sections were prepared

and published during the administration of Dr. L. L. Hubba (1893-1899).[24] With the help of these records and the work Winchell and Rominger as a basis, Lane was enabled to much m completely and accurately represent the boundaries of the vario geological formations of southeastern Michigan upon a map companying Vol. V and bearing the date of 1893. The course the Sylvania sandstone is for the first time represented in t state and the Hamilton, omitted by Rominger, included under t name of the "Traverse". In Wayne County, the formations a represented as striking northeastward from Monroe and Wash naw counties, turning to the eastward as they approach Detr River. From the dolomites underlying the Sylvania (Lower Mo roe) at the extreme southern point of the county, the formatio in order of position and age are:—the Sylvania; the dolomi between the top of the Sylvania and the bottom of the Dund (Upper Monroe); the Dundee; Traverse; St. Clair (Antrim) sha and Richmondville sandstone. The Richmondville sandstone is garded as the geological equivalent of the Berea sandstone of Oh and referred to the Carboniferous, the position accorded the form tion by Winchell but united with the Devonian by Rominger.

During the administration of Dr. L. L. Hubbard, the writer w commissioned to make a survey of the county of Monroe and t field studies began in July, 1896, with a careful examination of t strata of the Sibley quarry, just north of Trenton, and the natu and artificial exposures of the beds of rock along the Detroit a Huron rivers. An extensive collection of fossils was then ma which has furnished the basis for the palaeontological chapter p pared for this report by Prof. A. W. Grabau. The subseque field work in Monroe County in 1896, 1897 and Sept. 1899, with t maps and reports based upon the same, furnished the key to an u derstanding of the surface features and geological structure much of Wayne County. The survey of this county was auth ized by Dr. Alfred C. Lane, (State Geologist from 1899 to 190 and portions of the field seasons of 1902 and 1903 were devoted a detailed study of all its geological features. The final prepa tion of the completed report upon the county has been delay until the U. S. topographic maps were available, covering the e tire region, and until the shaft of the Detroit Salt Company h given us the long-wished-for record of the series of rock strata southeastern Michigan. In the meantime further valuable w

24. Vol. V, Geological Survey of Michigan, 1895, pt. II; edited by Dr. A. C. Lane, t assistant state geologist.

records have been collected and much information obtained through the help of co-laborers in the territory immediately adjacent, or overlapping.

Messrs. Frank Leverett and Frank B. Taylor, of the U. S. Geological Survey, have been diligently working out the surface features and the glacial history of this region for a monograph now in preparation. In the summer of 1904, Mr. Leverett and Myron L. Fuller, also of the U. S. Geological Survey, investigated the shortage of water in the lower Huron basin, examining a strip in Wayne County and the corresponding portion of Monroe. Rev. Thomas Nattress, of Amherstburg, Ontario, has studied the strata of the Anderdon quarry and of the bed of the Detroit River adjacent and collected interesting suites of fossils from the same. In August, 1907, Prof. A. W. Grabau, of Columbia University, spent a week with the writer in a direct study of the geological formations exposed along Detroit River and about the western end of Lake Erie. To him have been submitted all the fossils collected from the dump of the salt shaft at Oakwood and to him we are indebted for the subdivisions of the geological column. The Ann Arbor Folio, No. 155, of the U. S. Geological Survey, published in 1908, contains a geological sketch map of the Ann Arbor quadrangle by the late Prof. I. C. Russell, of the University of Michigan, as well as maps of the soil and surface features by Mr. Leverett. This quadrangle includes a narrow strip of Wayne County and all that region immediately to the west, thus contributing much to our knowledge of the geology of Wayne County itself. Based upon all the data available from the work of the State and United States geological surveys, Mr. John F. Nellist, of Grand Rapids, has prepared a colored map of the entire lower peninsula of Michigan giving the soil and surface features. This map was issued in connection with the Ninth Annual Report of the State Geologist for the year 1907, published in 1908; accompanying a paper of Lane on the surface geology of the state. Since the pioneer work of Higgins in the late 30's this is the first attempt to map the surface features and soils of Wayne County, and, considering the small scale of the map, these features are very satisfactorily shown. A revision of this map has now been made which has corrected some errors and permitted the insertion of later data. The new soil map has been issued on a smaller scale but more soil details are shown than on the older and much larger map. A new text upon the surface geology with special reference to agricultural conditions has also been prepared by Frank Leverett of the U. S. Geological Survey to accompany this map.

CHAPTER II.

GLACIAL HISTORY OF THE HURON-ERIE BASIN.

THE ICE INVASION.

Present importance. The key to an understanding of the present physical features of Wayne County is found only in a study of the late geological history of southeastern Michigan and the territory adjacent. Taken by themselves, these physical features never could have been fully deciphered, but, in connection with those of the entire area, they lend themselves to clear and accurate interpretation. Improbable as it may seem to the ordinary reader, they point back, in comparatively recent geological time, to a period of ice sheets of great dimensions and glacial lakes at levels considerably above those of our present system. The rocky strata of earlier geological age and the soils resulting from their decomposition have been covered up or swept away through the agency of this ice. The old surface features, developed through the untold ages of middle and subsequent earth history, were obliterated and new ones superposed.

A farmer of the county wishes to learn why his section is rolling and another is flat, why his farm is strewn with boulders, while that of his neighbor is not so encumbered; why he can raise corn and wheat, his neighbor only beans and rye; why he can have a flowing well while his neighbor must be content to do his pumping by hand, or go to the expense of installing a windmill. The urbanite may wonder what determined the site of his home city and what will be its most probable direction of growth, or why the soil of his garden or lawn is sand rather than clay or gravel. He is more actively interested in learning how deep he must go for a secure foundation for his office building or manufacturing plant, the amount and type of sewer system required and what is his share of the expense of the bond issue for good roads. To answer such inquiries fully, there must be recounted the story of the great ice invasion from the Canadian regions to the north and east.

Formation of the ice sheets. Very long ago as man reckons time;—say 300 to 400 thousand years, but geologically speaking, only yesterday, there was started in the highlands of the Labrador peninsula a great snow field, more snow falling during the winters

than could be melted during the summers. Geologists are not yet agreed as to the exact set of causes which brought about this condition in this particular region and other sections of the northern hemisphere. Numerous theories have been proposed which may be at once discarded; such as, the shifting of the earth's axis, the sliding of the earth's crust on the molten interior, the secular loss of heat by the earth or sun, or the obscuring of the sun by sunspots or meteoritic matter. The theories which have received the most attention from geologists are based:—

1st. On a particular distribution of land and sea, causing a maximum of refrigeration and permitting favorable atmospheric and marine currents.

(Lyell and Dawson).
Principles of Geology, Lyell, 7th edition, 1847, Chapter VII, p. 93.
The Canadian Ice Age, Dawson, 1894, Chapters III and IV.

2nd. Greater elevation of the lands in the regions of accumulation.

(Dana and Upham).
Manual of Geology, Dana, 3rd edition, 1880, p. 540.
On the Cause of the Glacial Period, Upham, American Geologist, vol. VI, 1890, p. 327.
Appendix to Wright's Ice Age in North America, Upham, 1889, p. 585.

3rd. A certain shape of earth orbit by which there were produced long cold winters and short hot summers.

(Croll and Ball).
Climate and Time, Croll, 1875, chapter IV, p. 54.
Climate and Cosmology, Croll, 1886, chapter III, p. 38.
The Cause of an Ice Age, Ball, 1891, chapter V, p. 78.

4th. A diminution in the amount of the carbon-dioxide ingredient of the atmosphere, wherby there is permitted excessive radiation of heat from the earth.

(Tyndall, [illegible]nius and Chamberlin).
Tyndall, Heat considered as a Mode of Motion, American revision of second edition, 1867, p. 363. Sixth edition, 1905, pp. 344 and 413.
Aarhenius, On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground: Philosophical Magazine, 5th Series, vol. XLI, p. 237.
Chamberlin, An Attempt to Frame a Working Hypothesis of the Cause of Glacial Periods on an Atmospheric Basis: Journal of Geology, vol. VII, 1899, p. 752. Geology, Chamberlin and Salisbury, vol. III, 1906, p. 432.

Geologists are disposed to believe that two or more, possibly all of these factors may have conspired to bring about glacial conditions in certain areas,[1] and are agreed that there was an uplift to the north and an increase in precipitation in the form of snow. Tyrrell, of the Canadian Geological Survey, reports finding snow in mid-summer in isolated patches of the Keewatin region to the west of Hudson Bay and concludes that a slight increase in the amount of precipitation, or a slight reduction in the annual temperature, would again mantle the region with snow and ice.[2] Once started, such a covering would tend to still further lower the mean annual temperature of that section and to assist in the establishment of conditions favorable for glaciation.

1. See Lane's paper Summary of the Surface Geology of Michigan, Report of the State Board of Geological Survey of Michigan for 1907, p. 97.
2. The Glaciation of North Central Canada: Journal of Geology, vol. vi, No. 2, 1898, p. 160.

Year after year the snow field would thicken and extend its area about the margin, gradually becoming compacted into ice through pressure, summer melting and rainfall. Owing to a peculiar and, as yet, little understood property of ice, this mass would *act* as if *plastic* under its own weight and gradually creep out in all directions from the central area of accumulation. A continuance of

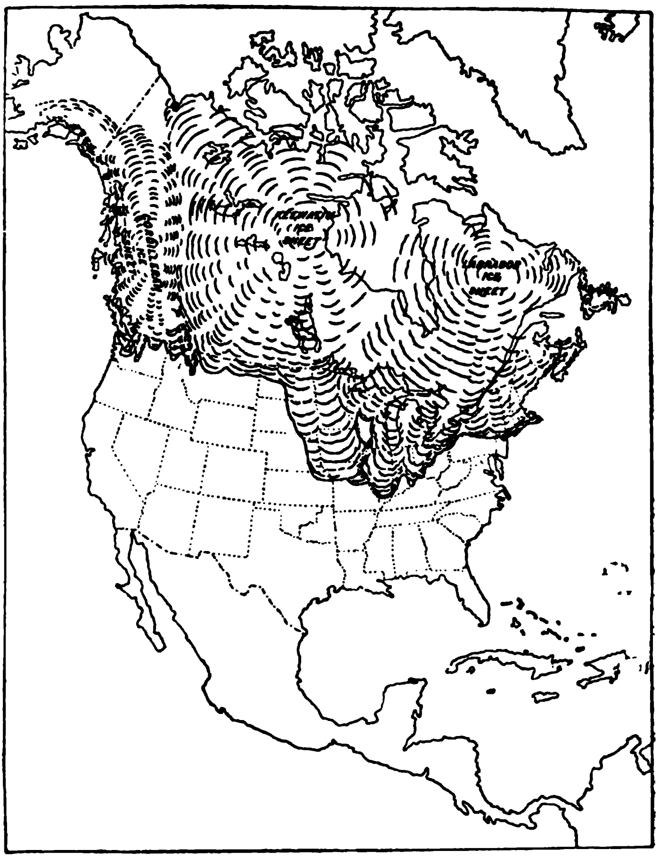

Fig. 9. Sketch map. Extent to which the ice sheet covered North America. After Chamberlin and Salisbury's Geology. Patrician center not shown.

the conditions established would compensate for the loss from this flowage, the oceans supplying the moisture and the sun the necessary heat for its evaporation and transportation by the wind, until a great continental ice sheet came into existence comparable with that of Greenland, or Antarctica. Similar ice sheets had previously formed to the west, one centering in the Keewatin region just west of Hudson Bay, another in eastern Manitoba between

Hudson Bay and Lake Superior and yet another over the Great Cordilleras of western Canada. These centers of accumulation and dispersal and their maximum extent are shown approximately in fig. 9.

Whether or not the Keewatin and Manitoban (Patrician) ice fields reached southeastern Michigan remains undecided though probable,[3] but certain it is that the Labradorean sheet spread over the region as far south as the Ohio and from the Atlantic to the Mississippi, covering an area of hundreds of thousands of square miles, attaining a possible thickness of two miles, or more, and moving out from the center some 1,600 miles. The main movement was to the southwest directly athwart which lay Michigan, at just the right distance from the center as well as from the margin to receive the full force of the attack. Thus located and, with the maximum of international boundary, Michigan was compelled to bear the brunt of this great Canadian ice invasion. The movement may have averaged no greater than a foot a day, but it was continuous over a very long period and was practically resistless in its power. The animal life was driven from the region, or destroyed, the soil and all vegetation pushed ahead of the ice, or incorporated into the basal layers and thus removed. The rock strata then exposed were planed down, fluted or grooved, scratched and in places polished. Fragments of these strata were detached and removed, some of them large enough to be mistaken for outcrops of bed rock.[4] This highly effective type of ice action is shown in Pl. I, from the Canadian Rockies. Where the topography, nature and structure of the rocks were favorable, great basins were excavated which became the sites of the Great Lakes, these being modified from preglacial erosion valleys. The final result was the production of enormous quantities of gravel, sand and rock flour, which when lodged beneath, or about the margin of the ice, gave rise to till, or when assorted more or less by running water to various forms of stratified deposits.

There is geological evidence that a general depression of the region occurred, probably due to the heavy weight of the ice mass itself, followed by an amelioration of the climate and a retreat of the ice to an unknown distance northeastward. A partial restoration of the conditions favorable for glaciation led to the formation of at least two additional ice masses and subsequent advances over southeastern Michigan, each less vigorous than the first and

3. Leverett, Review of the Glacial Geology of the Southern Peninsula of Michigan: Sixth Report of the Michigan Academy of Science, 1904, pp. 101 and 104.
4. See Winchell in American Journal of Science, second series, vol. XL, 1865, p. 331.

separated by shorter intervals of time. Each ice sheet destroyed, or modified the work of the preceding, so that the present physical features of this region are to be attributed, in the main, to the last sheet, so far as they have not since been modified by aqueous or aeolian agencies. The destructive work above noted was accomplished during the stages of ice advance, while during stages of retreat, or of marginal halt, the material transported by the ice found lodgment in sheltered places, or was built into various topographic forms to be described. It has been estimated that the Lower Peninsula of Michigan is mantled by such glacially worked material to an average depth of about 300 feet,[5] made up of preglacial soil, disintegrated local strata and similar material from the northeast. No satisfactory data are at hand for estimating even approximately the amount of denudation suffered by our state as the combined result of this ice action. It is quite probable that the material supplied to it from outside was in excess of that taken from it to help make up the deposits to the south and west.[6] Economically it will be shown that the Glacial Epoch was of vast importance to the state in its contribution of soil, lakes and water power.

Illinoian ice sheet. Owing to its extension into Illinois and the opportunity there afforded for a study of the deposits left by this ice sheet during its waning stages this, the first of the great ice masses from the Labradorean center, has been so named.[7] It represented the maximum extension of ice from this center, was presumably the thickest and was largely responsible for the ice erosion in southeastern Michigan. Had it occurred last there would probably have been no identifiable trace of the earlier ice movements. Where the direction of movement coincided approximately with the strike of the rock strata, as it did in Wayne and Monroe counties, there were excavated broad, shallow troughs and basins, in the softer beds, separated by low, rounded divides of more resistant rock, all now covered by subsequent deposits and traceable only by means of well borings. These troughs were mapped and described by the author in his report on Monroe County[8], the names used in connection with them referring to the geological strata in which they were carved. Were the covering of till re-

5. Cooper, Geology and Physical Geography of Michigan: Ninth Report of the Michigan Academy of Science, 1907, p. 140.
6. See paper by Lane, *loc. cit.*, p. 101.
7. Leverett, The Illinois Glacial Lobe: Monograph XXXVIII, United States Geological Survey, 1899. The name "Illinois" was first used by Chamberlin in an editorial in the Journal of Geology, vol. IV, 1896, p. 874, with credit to Leverett.
8. Geological Survey of Michigan, vol. VII, pt. I, 1900, pp. 122-124. See also a paper entitled Ice Work in Southeastern Michigan, Journal of Geology, vol. X, 1902, p. 197.

moved, they would serve as the beds of streams in Monroe County, while, in Wayne, they would be permanently occupied by arms of the Great Lakes. These troughs have their axes approximately parallel, ranging from S. 40° to 47° W. and averaging S. 43° W., pointing directly to the Labradorean center of ice accumulation.

In commenting upon this view of the writer Russell questioned the soundness of the evidence that these troughs were appreciably enlarged by the ice, remarking that the weaker rock strata would have been broken down to somewhat lower levels than the more resistant layers.[9] In reply it may be said that the mere breaking up of strata without removal of the debris would lead to the reverse of a trough and the shape of these troughs precludes the idea of the material having been removed by running water. Of the two main agencies left:—ice and wind, which might have operated most in removing such debris, I would select the ice as the most probable agent. The point was overlooked further, that these troughs become well defined only as the strike of the strata swings around into parallelism with that of the Illinoian ice movement over this section. In following these continuous depressions into Wayne County it was learned from the well records that a series of well defined rock-basins mark their course, which are generally accepted as convincing evidence of ice action (see Pl. XXV).

At the Sibley quarry, just north of Trenton, a large embossment of limestone served as a minor obstruction to the general ice movement. As the ice ascended this hill of firm rock it plowed more deeply into the layers that were able to withstand the plucking action and there were excavated on the so-called "stoss-side" a series of parallel grooves and basins, some 10 to 30 feet across and from 2 to 10 feet deep so far as seen (see Pl. II, A.). The axes of these great furrows have an average trend of S. 42° W., practically identical with that of the greater troughs above noted and presumably belong to the same system. The close parallelism of these glacial features, directly across such obstructions, indicates a very steady movement and consequently a relatively large ice mass. For every 1,000 feet of thickness the pressure of such a mass upon the underlying rock was some 28.5 tons to the square foot, so that its eroding power need cause no great surprise when a great length of time is allowed for its action.

In a portion of the bed of Detroit River, laid bare in the excavation of the Livingstone Channel, opposite Stony Island, a series of shallow, approximately parallel grooves, (see Pl. II, B) two to

9. Ann Arbor Folio, No. 155, 1908, p. 2.

four inches across, were noted ranging S. 35°-45° W. Associated with these were patches of delicate striae averaging (35 observations) S. 41.8° W. These evidences of glaciation were protected from subsequent ice action, as well as that of the river, by a bed of very compact, stony, rusted till believed to be of Illinoian age (Pl. III, A.). The import of this discovery is that we have now convincing evidence that the Illinoian ice actually moved across this region in the direction indicated by these great troughs and furrows.

A diminution in the amount of snowfall over the area of accumulation, or increased melting due to an amelioration of climate, probably both these factors combined, brought about a more sluggish condition of the ice and finally inaugurated a retreat of the ice margin. The ice is to be thought of as constantly advancing at approximately right angles to the ice front owing to the weight and pressure of the greater mass behind. When the marginal melting was greater than this average forward movement of the ice mass, the margin seemed to retreat; when the average rates of melting and forward movement were equal, the margin appeared to halt, while a slight excess of movement at any time might cause a temporary advance of the ice front. Plates III, B. and IV, A. and B. from the writer's report upon the Canadian glaciers show such conditions of the ice margin. From what is known of modern glaciers there is reason for thinking that the retreat of such an ice sheet would be very slow and characterized by periods of halt and temporary advance. Taylor has presented evidences for thinking that such a movement would be periodic and hence rhythmic[10] and has endeavored to show that the procession of the equinoxes may have influenced climate sufficiently to have produced such a type of retreat and led to the symmetrical spacing of the frontal moraines formed during stages of halt. Whatever topographic features were produced in southeastern Michigan by the retreating Illinoian ice sheet, all have been destroyed by subsequent ice advances and there remain only the effects produced upon the rock surface, obscured by glacial debris but not entirely obliterated. In certain places where conditions were especially favorable, there was a deposition beneath the ice of rock fragments, gravel, sand and rock flour in a heterogenous compact mass known as "till". None of this material referable to the Illinoian was encountered in either of the two salt shafts, or in the Detroit River tunnel but so-called "hard pan" is frequently reported by well drillers of

10. Moraines of Recession and their Significance in Glacial Theory: Journal of Geology. vol. V, 1897, p. 421.

Wayne County just overlying the bedrock. This varies in thickness from a few inches to several feet and may represent fragments of the Illinoian till-sheet not removed by the later ice movements.

At the southern end of the Livingstone Channel previously referred to, overlying the supposed Illinoian glaciation, there occurs a very hard, stony and rusted till (Pl. III, A. and Pl. V, B.) which appears to be of Illinoian age. The deposit proved to be so hard that much difficulty was experienced in removing it by means of a powerful steam shovel. Pebbles from this deposit when placed alongside of those from the later Wisconsin, indicate greater age, the limestones especially showing a thin, mealy coating which has obliterated, to a large extent, the delicate scratches so often shown by limestone fragments from the younger till. An interesting relation was found to exist between this deposit and the rock topography, apparently explaining its preservation in this particular locality. At the northern end of the channel an anticlinal fold crosses the river in an east-west direction, the crest of which has an elevation of approximately 568 to 569 feet above sea level. One mile south the surface of the till deposit is 568 feet, upon either side of the channel, but the rock surface is 560 feet upon the west side and 554 feet upon the east, giving a thickness to the till of 8 to 14 feet. Towards the north, the till diminishes in thickness as the rock surface rises, forming a broad wedge in the lee of the anticline (see Pl. V, A.), from which protected position it was not removed by subsequent advances of the ice. In the vicinity of Detroit River light, Lake Erie, an unusually hard variety of till was encountered by the dredges and is also very probably of Illinoian age. At the pit of the American Silica Company, near Rockwood, some 14 to 16 feet of an exceptionally hard clay overlies the sandstone, so hard that it was at first found necessary to blast it out. Later it was found possible to remove it by means of a powerful steam shovel. The lower portion is stony, the upper not so much so and the whole probably also represents another fragment of this older till.

Iowan ice movement. A supposed movement from the Labradorean center has been recognized as the Iowan,[11] of much later

11. The term "East-Iowan" was first made use of by Chamberlin in the third edition of Geikie's Great Ice Age, 1901, page 759, for an extensive till-sheet developed in southeastern Iowa. This name was shortened to *Iowan* in 1895 (Journal of Geology, vol. III, 1895, pp. 270 and 273) when it was discovered by the work of the Iowa Geological Survey that the till-sheet to which it was applied was the same as the Kansan. A year later Chamberlin consented to the transference of the name Iowan to a much younger and less well developed till-sheet in the northeastern corner of the state. See—
Chamberlin, Editorial in the Journal of Geology, vol. IV, 1896, p. 872.
Calvin, Synopsis of the Drift Deposits of Iowa: American Geologist, vol. XIX, 1897, p. 270.
Iowa Geological Survey, vol. VII, 1897, p. 18.
Iowan Drift: Bulletin of the Geological Society of America, vol. 10, 1899, p. 107.

age than the Illinoian and presumably older than the Wisconsin. Michigan lying directly in the path between its center of dispersal and the state of Iowa, where the till deposits have been most fully recognized, must have been crossed by this ice movement. Recent investigations of Leverett, however, have led him to question the soundness of the evidence of such a stage.[12] In his presidential address before the Geological Society of America, December, 1908,[13] Calvin asserts the distinctness of this drift sheet from all the others, but describes it as meager in amount and scrappy in character. The movement into Iowa was from the *northwest* (p. 144), covering only the northeastern quarter of the state and it did not reach the region that had been visited by the Illinoian ice. In view of these facts it must be regarded as uncertain whether or not such an ice sheet ever crossed this section of Michigan. In studying the glacial striae of Wayne and Monroe counties, the writer has found a set having the general direction of W. SW. (S. 65 to 78° W.), older than the late Wisconsin and younger than the Illinoian, which might very plausibly be referred to the Iowan in view of their age and course. If this stage, however, is to be eliminated these striae will have to be regarded as having been made during an early phase of the Wisconsin stages.

Between the withdrawal of the Illinoian ice sheet and the arrival of the Wisconsin, there was a relatively long time interval which gave opportunity for pronounced weathering of the deposits and marked erosion by the streams. The soils were rusted to a considerable depth, the lime carbonate leached out and the rock fragments considerably decayed. The growth of vegetation in places gave rise to beds of humus and muck which when not removed. give a very distinct dividing line between the Illinoian till and later deposits. The term Sangamon soil, or the Sangamon weathered zone, has been used to designate the one formed immediately upon the Illinoian till.[14] Between the supposed Iowan till. or the loess deposit correlated with it, a second such soil, known as the Peorian, or Toronto, has been recognized. In sections. where neither till nor loess of Iowan age was present, these two soils would be superposed and indistinguishable from one another. Rather indefinite and uncertain traces of these buried soils have been found in well records in southern Wayne and northern Mon-

12. Weathering and Erosion as Time Measures: American Journal of Science, vol. XXVII. fourth series, 1909, p. 367.

13. Bulletin of the Geological Society of America, vol. XX, 1909, p. 146. See also paper "The Iowan Drift," read at the Pittsburg, 1910, meeting of the Society.

14. Leverett, Journal of Geology, vol. VI, 1898, pp. 176 and 244.
See also paper Weathering and Erosion as Time Measures: American Journal of Science. fourth series, vol. XXVII, 1909, p. 349.

QUARTZITE BLOCKS DISRUPTED BUT NOT REMOVED BY ANCIENT GLACIER, CANADIAN ROCKIES. (COURTESY SMITHSONIAN INSTITUTION).

ERRATA.

The cut of the nose of the Victoria Glacier, now shown upon Plate I, should have been placed upon Plate III B. The disrupted quartzite blocks called for upon Plate I are shown upon Plate IV A, while the retreating face of the Victoria Glacier appears upon Plate III B. Titles will be found to be correct as printed. For Plate XXXIX read XXIX.

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and the state of Iowa, where the till deposits have bee
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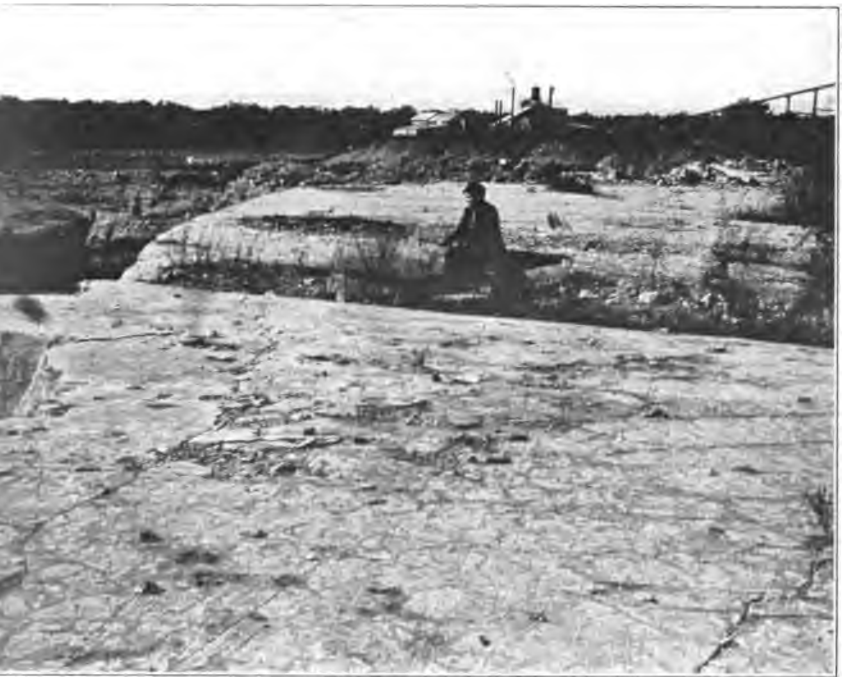
GLACIAL TROUGHS, ILLINOIAN AGE, SIBLEY QUARRY. IN THE FOREGROUND IS SHOWN THE GLACIATION DUE TO THE WISCONSIN ICE.

ILLINOIAN GROOVING AND STRIATION, LIVINGSTONE CHANNEL, DETROIT RIVER.



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NEAR VIEW ILLINOIAN TILL, LIVINGSTONE CHANNEL. THE VERY STONY
RACTER OF THIS TILL MAY BE CONTRASTED WITH THAT OF THE WISCON-
PL. VI, A, AND PL. VIII.

STATIONARY NOSE OF VICTORIA GLACIER, CANADIAN ROCKIES. (COURTESY
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TATIONARY NOSE OF VICTORIA GLACIER, CANADIAN ROCKIES. (COURTESY SMITHSONIAN INSTITUTION).

A. RETREATING FACE OF VICTORIA GLACIER.

B. ADVANCING FRONT OF WENKCHEMNA GLACIER, CANADIAN ROCKIES.
(PLATE IV A & B COURTESY SMITHSONIAN INSTITUTION

A. RETREATING FACE OF VICTORIA GLACIER.

B. ADVANCING FRONT OF WENKCHEMNA GLACIER, CANADIAN ROCKIES.
(PLATE IV A & B COURTESY SMITHSONIAN INSTITUTION

A. DISTANT VIEW ILLINOIAN TILL DEPOSIT, LIVINGSTONE CHANNEL, DETROIT RIVER. THE UNDISTURBED WEDGE OF TILL LIES JUST BENEATH THE DUMP AND MANTELS THE BEDROCK.

B. NEAR VIEW ILLINOIAN TILL, LIVINGSTONE CHANNEL.

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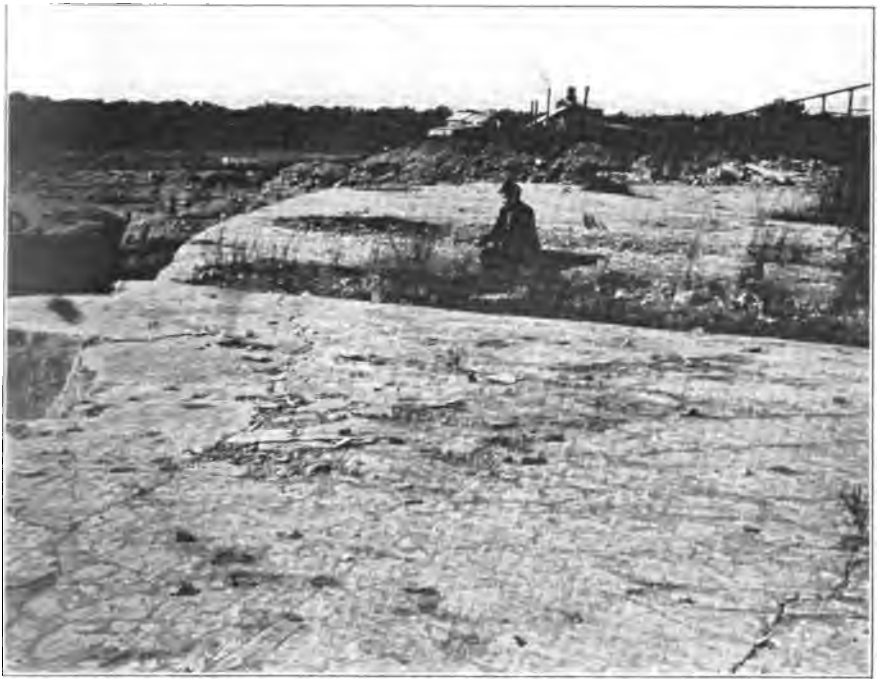

.. GLACIAL TROUGHS, ILLINOIAN AGE, SIBLEY QUARRY. IN THE FOREGROUND IS SHOWN THE GLACIATION DUE TO THE WISCONSIN ICE.

. ILLINOIAN GROOVING AND STRIATION, LIVINGSTONE CHANNEL, DETROIT RIVER.

A. NEAR VIEW ILLINOIAN TILL, LIVINGSTONE CHANNEL. THE VERY STONY HARACTER OF THIS TILL MAY BE CONTRASTED WITH THAT OF THE WISCONSIN; PL. VI, A, AND PL. VIII.

. STATIONARY NOSE OF VICTORIA GLACIER, CANADIAN ROCKIES. (COURTESY SMITHSONIAN INSTITUTION).

LENGTHWISE VIEW OF GLACIAL TROUGH, SIBLEY QUARRY. THE STRIAE SHOWN ARE DISCORDANT WITH THE TROUGH AND PROBABLY OF EARLY WISCONSIN AGE.

LAMINATED WISCONSIN TILL, SIBLEY QUARRY. THIS STRUCTURE IS BELIEVED TO BE DUE TO THE MOVEMENT AND GREAT WEIGHT OF THE ICE.

WISCONSIN TILL AND GLACIATED BEDROCK, SIBLEY QUARRY. NOTE THE STONY CONDITION OF THE TILL JUST OVER THE BEDROCK.

LENGTHWISE VIEW OF GLACIAL TROUGH, SIBLEY QUARRY. THE STRIAE SHOWN ARE DISCORDANT WITH THE TROUGH AND PROBABLY OF EARLY WISCONSIN AGE.

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roe counties, suggesting that remnants of them may still be there preserved.[15] Leverett has estimated that the amount of stream erosion indicated upon the surface of the Illinoian till, where it was not subsequently covered, is five times greater than that shown by the youngest, or late Wisconsin sheet. If we postulate similarity of rainfall and drainage conditions, this would indicate that the interval from the withdrawal of the Illinoian ice to the final disappearance of the ice sheets in this region was four times as great as the time that has since elapsed.

Wisconsin ice movements. Two related movements, an early and late, have been termed Wisconsin, because of typical exposures of the various deposits in that state and their early studies there.[16] They were related in point of time, being separated by a relatively short interval, which gave but little additional time for the weathering and erosion of the earlier deposits, when not covered by the later.[17] The earlier was the more massive and vigorous, extended farther westward and southward and, upon its retreat to an unknown distance, left behind its characteristic till-sheet, moraines, etc. Its distribution did not entirely coincide with the Illinoian, but, wherever such was the case, the topographic features left by the Illinoian, or developed subsequently, were obscured or entirely obliterated. In many places, the bedrock was entirely denuded and received a new set of glacial striae or furrows. The detritus which the Early Wisconsin found in its path was mixed in with that which it was able to manufacture, or acquire anew, and the whole worked into a much younger and fresher till-sheet, which it deposited during its waning stages with more or less regularity (see Pl. VI).

The interval between the retreat of the Early and the advance of the Late Wisconsin permitted the introduction of factors which caused a deflection of the general direction of movement more to the westward. This effect may have been brought about by a shifting of the main center of snow accumulation, a change in topography due to the work of the Early Wisconsin itself, or by a relief of pressure of ice masses to the north. This second movement fell short of the first both toward the south and west, but so far as they covered the same territory the effect was the same as that noted above. Where one till-sheet still overlaps the other, there

15. See writer's Geological Report on Monroe County: Geological Survey of Michigan, vol. VII, pt. I 1900 p. 126.
16. The term "East-Wisconsin" was first proposed by Chamberlin (third edition of Geikie's Great Ice Age, 1901, p. 763) for these till-sheets so well exposed in this state. At the suggestion of Upham the name was shortened to *Wisconsin*. (Journal of Geology, vol. III, 1895, p. 270.)
17. See Leverett, American Journal of Science, vol. XXVII, fourth series, 1909, p. 351.

is no practical way of distinguishing between them, based either on the nature of the material present, its condition, or on any line of demarcation, such as that noted between the Illinoian and Early Wisconsin. A study of the glacial striae of southeastern Michigan shows that the last recorded movement was *northwestward*, pronouncedly so at the Sibley quarry, swinging around toward the west over the northern half of Monroe County and to west-southwest in the southwestern corner. These striae were without doubt made by the lobe of ice which filled the Huron-Erie basin, after it had separated from the neighboring lobes upon either side, this region lying upon the northwestern side of the lobe and the motion being approximately at right angles to the ice margin. At the Sibley quarry the average bearing of the striae was found to be about N. 29° W.,[18] with a range of some 43°. This rather wide range (N. 43.5° W. to N. 0.5° W.) would indicate that the ice lobe at the time was free from its neighbors and subject to minor disturbance. The next oldest set of striae studied at the Sibley quarry gave a range of but 20° and averaged about S. 31° W., giving an angle of 120° with the later movement. If these striae are referred to an early phase of the Late Wisconsin, we should expect them to be connected with the later set by an entire series of striae having an intermediate course and produced, as the Huron-Erie ice lobe was being separated from the main body of ice. Such intermediate striae were not found, however, although a more thorough search might have revealed them. The present inference then is that the set of striae to the S. SW. should be connected with the Early Wisconsin movement, while the still older series, having the general bearing W. SW., should be regarded as due to an earlier, more westerly direction of movement of the same ice mass.

The general effect of the Wisconsin ice sheets upon the bedrock about Detroit River and the western end of Lake Erie seems to have been relatively slight, even at the Sibley embossment, where we should expect to find the maximum effect. The upper surfaces of the limestone and dolomite were planed down and smoothed, but received at the same time innumerable parallel, or slightly diverging, scratches and gouges caused by sand grains, pebbles and boulders held in the basal layers of the ice (see Pls. II, A., VI, and VII). The criteria for determining the direction of ice movement have been most satisfactorily described and figured by Chamber-

18. A table of the bearings of glacial striae in Monroe County is given in the author's report on this county, *loc. cit.*, p. 131.

lin,[19] to whose very complete paper the reader, interested, is referred. At the Sibley quarry, although 80 acres of beautifully glaciated limestone surface have been destroyed, all these various criteria may still be found by the investigator who knows just what to look for. The glimpses of the rock surface here afforded and at other isolated patches in this corner of the state, lead us to infer that the entire rock surface of the region was similarly affected by the Wisconsin ice, except where protected sufficiently by the Illinoian till-sheet, as at the Livingstone Channel and elsewhere.

Although interesting from a geological standpoint the destructive work of the Wisconsin ice masses is far overshadowed in importance by their constructive work. Spread over the rock surface, filling the hollows and subduing the general relief of the entire region, was a heavy mantle of bluish-gray till, similar in character to that left by the Illinoian ice but much fresher and less indurated. Formed beneath the ice while still in motion this deposit is often referred to as the "ground moraine", while the even surface imparted to the deposit gave rise to a "till plain." This deposit ranges in thickness from zero, in southeastern portions of Wayne County to 170 to 180 feet in the northern part of Hamtramck and the northeastern corner of Van Buren townships (see Pl. X). Spread evenly over the surface, it might average from 70 to 80 feet in thickness. The deposit consists, in the main, of a compact, bluish, and unstratified clay, charged with pebbles and boulders, nearly all of which show facets, striae or give other evidence of glacial abrasion. A majority of these pebbles and boulders in this region consists of limestone, or dolomite, well fitted for receiving these evidences of glacial action. Although the till is unstratified, there has been developed at times in it a lamination, the result of ice pressure and movement, best seen when the vertical face has dried somewhat and shrinkage cracks have developed. This structure is shown in Pl. VIII taken at the Sibley quarry in August, 1911. Compared with the Illinoian till, the Wisconsin is characteristically soft, it being sometimes difficult to force a knife-blade into the former and exceedingly difficult to penetrate it in wells. A large body of Wisconsin till will creep, or flow under its own weight, which phenomenon caused the abandonment of the salt shaft of the Michigan Rock Salt Company, at Ecorse, in 1902. In general, the surface of the Wisconsin till shows some evidence of weathering, more or less rusting of the iron present having taken

19. The Rock-Scorings of the Great Ice Invasions: Seventh Annual Report of the Director of the U. S. Geological Survey, 1888, p: 244 to 248.

place. The greatest amount of such discoloration reported was in the vicinity of Windsor, Ontario, where it is said to extend to a depth of 25 feet. Tested with acid there is little recognizable leaching of the lime carbonate from the till, which is interpreted as indicating a relatively short exposure to atmospheric action. In this respect it does not differ essentially from the Illinoian till which may be due to the fact that the upper, more leached portions of the latter were swept away by the Wisconsin ice.

During periods of halt, or temporary advance, the retreating Late Wisconsin, built up along its broad front ridges and mounds of till deposit, resting upon the main till-sheet and forming the so-called frontal moraines. Boulders and cobbles carried on, or within the ice were brought to the margin of the ice by its continuous forward movement and strewn over the morainic features there formed. In contrast with the rock fragments found in the ground moraine, these consist very largely of the crystallines;—granites, gneisses, greenstones, etc. and very few of them show signs of glaciation. In retreating across Wayne County, there were apparently two periods of halt (see Pl. X) of the ice front, during which no morainic features were built up, and indicated only by a concentration of these boulders and cobbles. A uniform retreat of the ice from the pronounced morainic structures in the northwestern portion of the county to the more subdued morainic features of the eastern section would have strewn the boulders, that happened to be carried by the ice, somewhat uniformly over the intervening till plain.

Running water, resulting from the melting ice or from rainfall. carried from beneath the ice sheet quantities of clay, sand and gravel. The easily transported clay was carried to considerable distances before it could find favorable conditions for lodgment, but the sand and gravel were often deposited in the vicinity of the ice margin, frequently forming mounds, more or less elongated, known as kames, (Pl. IX A. and B.) at the time that the frontal moraines were in process of formation; sometimes filling and clogging the subglacial tunnels, giving rise to eskers, or spreading out in a broad sheet beyond the ice margin and thus forming outwash plains, or aprons. An advance of the ice over such deposits, or similar ones that may have formed locally beneath the ice, sometimes resulted in their being covered with a sheet of till and their being thus incorporated in the general ground moraine. Such deposits being porous and permeable by water become of great eco-

nomic importance to the inhabitants of the region, as will appear in the chapter on water supply.

LACUSTRINE HISTORY.

Formation of the lakes. When the ice had withdrawn northward from the low divide separating the Erie drainage from that of the Ohio basin, the water began to be ponded back between this divide and the ice front, which served as a dam, preventing the water from following its present course of drainage. Small, isolated bodies of water would first be formed along the ice front, which would gradually combine as the water level rose and a single lakelet would result. When the supply of water from the melting ice sheet and that supplied by ordinary precipitation was sufficient to raise the level of the lake to that of the lowest rim of the divide, or of the ice dam itself, an outlet would be formed and the drainage of the lake would begin. As a result of wave action about the land-locked portion of the lake, a beach would begin to take form, the gravel and sand from the previously formed glacial deposits being washed into a low ridge about the water line, while the finer materials would be transported lakeward and there allowed to settle in the deeper and more quiet water. If the ice front remained stationary for a length of time, the bed of the drainage channel, especially if of ice or till, would be deepened by erosion and the level of the lake thus gradually lowered until the channel found a more resistent sill. A succession of rather poorly defined beaches would mark the stages in the lowering of the lake level. With sufficient time and water supply the bed of the drainage stream would be cut back to the lowest part of the lake bed, the lake would be drained and the additional water would be taken care of by a system of drainage channels flowing over the bed of the now extinct lake. Long before this could occur, however, the ice front had retreated until a lower outlet was uncovered, when the lake level would fall rather rapidly and without opportunity for a *succession* of beaches. If this second outlet was higher than the bed of the first outlet, there would be a stage during which both outlets would serve and this would continue until the bed of the second outlet was lowered by erosion sufficiently to draw off the entire discharge from the lake. Although the level, size, depth, shape and location of the lake might thus be subject to change it would be regarded as the *same* lake until a new outlet had been opened, when it should be designated by a new name. It is now proposed to trace the series of these glacial lakes, the predecessors

of our present Great Lakes, so far as they covered southeastern Michigan and made their beaches and clay deposits within the limits of Wayne County. Reference will be made to the writings of those who have had the most to do with deciphering this interesting history.

Lake Maumee. This, the first of the series, the oldest, the smallest and the highest, occupied at the beginning the present basin of Maumee River. It came into existence when the ice first began to retreat from the Fort Wayne moraine, which served as a restraining wall on one side, while the ice front served upon the other.[20] It soon assumed the shape of an arrow-head, the point

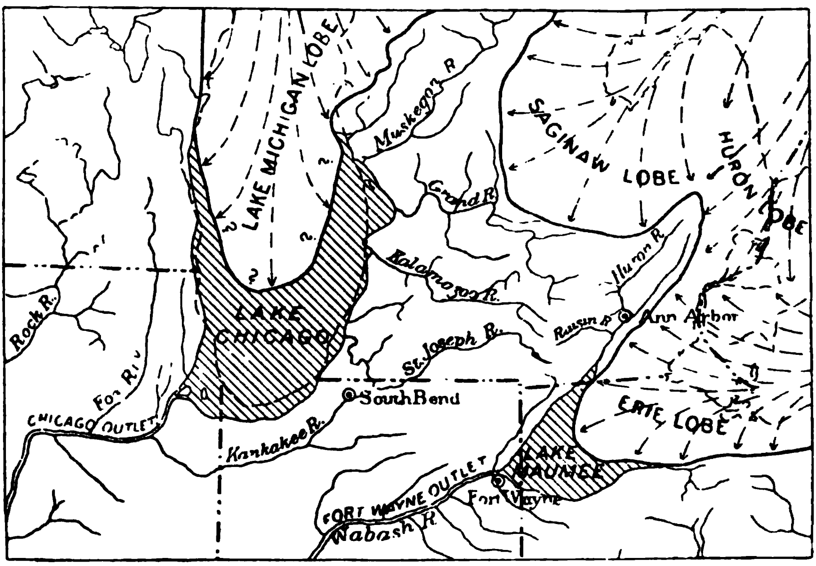

Fig. 10. Glacial Lakes Chicago and Maumee, first stage. After Frank Leverett.

being at the present site of the city of Fort Wayne, Indiana, one barb extending northward along the ice-lobe toward and into Michigan, the other eastward across northwestern Ohio. After leaving the Fort Wayne moraine the next place of halt for the ice front was the Defiance moraine, extending from Findlay, Ohio, by Defiance to Adrian, Michigan, giving a stretch of about 100 miles of ice wall, and a fairly definite size and shape to the lake. The water had risen to the level of the moraine at Fort Wayne and there found an outlet to the Wabash and thence to the Ohio. The lake

20. Dryer, The Erie-Wabash Region: Studies in Indiana Geography, 1897, p. 50. See also Geology of Allen County: Sixteenth Annual Report of the Department of Geology and Natural History of Indiana, 1889, p. 107.

at this stage of development is shown in fig. 10. It was some 40 miles wide in an east-west direction, 75 miles from Fort Wayne to Adrian and Findlay[21] and was 60 feet deep at Defiance. The elevation above present sea level was about 795 to 805 feet, the crest of the beach formed standing some 5 to 7 feet higher. Different sections of this beach in Ohio and Indiana were termed the Van Wert[22] and Hicksville ridges, from places located directly upon them, which names have been discarded and Upper Maumee beach substituted.[23] The two sections of this beach running from Findlay and Adrian respectively to Fort Wayne lead into the old channel which passes through the city and continues for 25 miles to Huntington, there entering the Wabash. According to Taylor this old outlet channel averages about a mile in width, is strewn with boulders and cobbles and represents a cut into the drift of some 20 to 80 feet, dropping very gradually down stream except in the last three miles where there is a more rapid descent over a sill of limestone.

When the time arrived for the ice to finally withdraw from the Defiance moraine, the water of the lake moved in between it and the retreating ice front and the barbs of the arrow-headed lake were extended eastward in Ohio towards Cleveland and northeastward across the northwestern corner of Wayne County. The beaches were thus extended at the original level, the outlet remaining the same, but, being younger and developed in relatively narrow arms, they do not show the strength of those portions lying between the Fort Wayne and Defiance moraines. The waters of the lake were thoroughly chilled by the great ice front as well as by floating ice bergs and the beach gravels show no signs of molluscan life. In Michigan, the main tributaries were the Raisin and Huron rivers, the latter entering the lake and building a conspicuous delta at Ann Arbor. When the retreating ice front had reached the site of Imlay City, in the eastern part of Lapeer County, a lower outlet than the Fort Wayne was uncovered and the waters of the glacial lake fell rapidly some 10 to 20 feet. This new outlet was from one-third to one mile wide, averaging

21. Taylor, The Great Ice-Dams of Lakes Maumee, Whittlesey and Warren: American Geologist, vol. XXIV, 1899, p. 23.

22. They were described by Klippart, without any names being assigned in his early Agricultural Survey of Ohio: Report of Progress of the Geological Survey in 1870, pp. 321 to 323; published in 1871.

For "Hicksville" see Dryer in Geology of Allen County, 16th Annual Report of Department of Geology and Natural History of Indiana, 1888, p. 109.

By each of the above writers, they were regarded as true beaches, but by N. H. Winchell as a peculiar type of *moraine* formed from "an unusual amount of water precipitated from the ice on the already deposited drift along its margin." Proceedings of the American Association for the Advancement of Science, Dubuque meeting, 1873, p. 175. The "Belmore Ridge," the beach of Lake Whittlesey, was believed to have had a similar history (page 179).

23. Taylor, *Loc. cit.*, p. 24. Leverett, Glacial Formations of the Erie and Ohio Basins: Monograph XLI, U. S. Geological Survey, 1901, p. 710.

about one-half mile, and being floored with sand and gravel indicates no great vigor of the drainage stream.[24] It led by Flint and Durand to Grand River, which discharged into glacial Lake Chicago, then forming at the head of the Lake Michigan ice-lobe (See fig. 11). This lake had its discharge southwestward to the Illinois and thence to the Mississippi.[25] The Imlay channel seems to have been neither low enough nor wide enough to have drawn the full discharge of the expanded lake and the Fort Wayne outlet also continued in commission for a time. The ice of the Huron lobe retreated eastward to the Imlay and Yale moraines, while the position of the ice front of the Erie lobe is not definitely known. being possibly represented by the Scofield and Grosse Isle halts of the ice margin. A new beach was formed at this lower level which was designated in Ohio the Leipsic beach,[26] but which is now generally referred to as the Second Maumee. The level of this lake may be given as 775 to 785 feet, above tide; the crest of the beach formed being a few feet higher. The full size, shape and location are made out by mapping the beach and locating the ice dam as shown by the course of the correlative moraine. This has been done and the result is shown in fig. 11.

Traces of a still lower beach, at an elevation of about 760 to 770 feet above tide, have been noted by Leverett east of Plymouth and Ypsilanti and described as the Third Maumee. This beach was also traced by the writer during the past summer northeastward from Plymouth into Oakland County lying just above the 760 foot contour, generally as a sandy belt and only exceptionally as a well defined ridge. South of the Huron, the beach, although faint, may be traced[27] but has the appearance of having been submerged after its formation and suggesting that it may have been formed before the completion of the Second Maumee. Future investigations may show that the ice had temporarily uncovered a lower outlet than that at Imlay City, forming a new member of the series of glacial lakes, and then by an advance had closed it and brought the level of the waters back again to that of the second stage of Lake Maumee. A gravelly deposit just east of Ypsilanti is believed by Leverett to represent the delta deposit of the Huron during this stage.

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24. Taylor, Surface Geology of Lapeer County, Michigan: Annual Report of the Geological Survey of Michigan, for the year 1901, p. 114.
25. For a description of this outlet see paper by Davis, The Ancient Outlet of Lake Michigan: Popular Science Monthly, vol. XLVI, 1895, p. 217. Also Leverett, The Pleistocene Features and Deposits of the Chicago Area: The Chicago Academy of Sciences, Bulletin No. II of the Geological and Natural History Survey, 1897, p. 57.
26. Leverett, On the Correlation of Moraines with Raised Beaches of Lake Erie: American Journal of Science, third series, vol. XLIII, 1892, p. 291.
27. Leverett, Ann Arbor Folio, No. 155; Atlas of the U. S. Geological Survey, 1908, p. 7

Lake Arkona. By the still further retreat of the ice margin toward the northeastward, there was developed a much larger water expanse, but at a lower level than the lowest stage of the Maumee lakes above described. In uncovering the "thumb", from the position of halt near Imlay City, lower ground than that of the Imlay channel was encountered and a new outlet or possibly a series of such outlets, opened to Grand River and Lake Chicago, giving rise to a lake now known as Lake Arkona.[28] The position of these outlets is not yet definitely known nor of the ice margin itself because

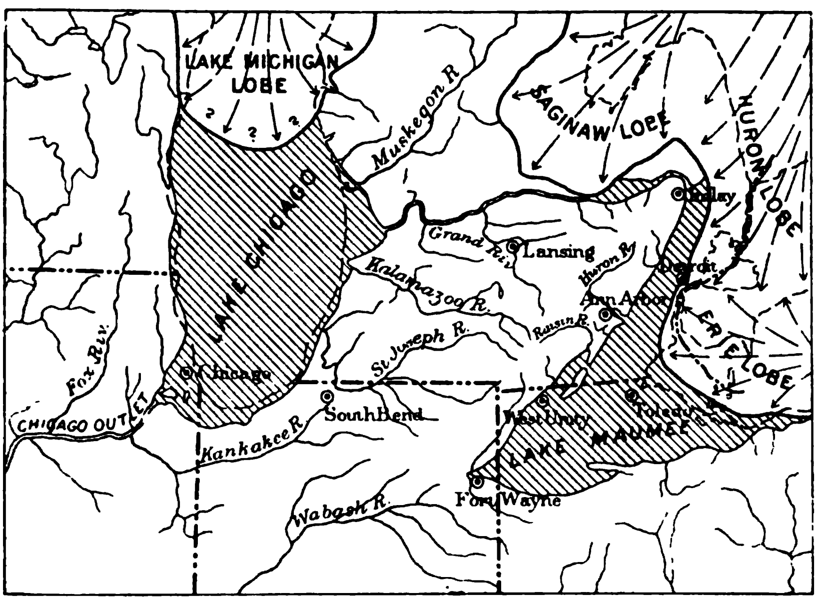

Fig. 11. Glacial Lakes Chicago and Maumee, second stage. After Frank Leverett.

of the pȧrtial destruction of the beaches and the correlative moraine by a re-advance of the ice, thus making it impossible to map the lake as has been done for the other stages.[29] The ice margin probably crossed the "thumb" and the bed of Lake Huron in a loop to the north of Port Huron. Three beaches may be recognized, with evidence of even a fourth, in the western part of Wayne County lying between 690 and 710 feet above sea level, or

28. Lane, Summary of the Surface Geology of Michigan: Annual Report of the Geological Survey for 1907, p. 128. The beach of this lake was given the name "Arkona" in 1891 by Spencer, from the village in western Ontario: American Journal of Science, third series, vol. XLI, 1891, p. 204. This beach was located at Denton, Wayne County, by Spencer himself and given an altitude of 694 feet above tide (p. 206), which elevation corresponds with that of the Third Arkona.

29. Taylor, Relation of Lake Whittlesey to the Arkona Beaches: Seventh Report of the Michigan Academy of Science, 1905, p. 29.

117 to 137 feet above the general level of Lake Erie. Taylor believes that the outlet was of the nature of a *strait* (*loc. cit.* p. 35) around the ice at its reëntrant angle between the Saginaw and Huron-Erie lobes, thus bringing Lake Arkona and so-called Lake Saginaw to the same level. As ingeniously worked out by this investigator, the beaches from Applegate and Croswell, on the eastern side of the "thumb" (Sanilac County) around to Cass City of the western slope, were overridden by the ice when it advanced from the position that it had held to that of the Port Huron moraine. He believes that these destroyed beaches were originally formed across the crest a little to the south of Bax Axe, Huron County. In thus advancing the ice closed up the strait, or other outlet and raised the level of the water to that of a channel crossing the crest of the "thumb" at Ubly and thus submerging those portions of the Arkona beaches lying to the south of Applegate and Croswell. Had this submergence of 20 to 30 feet taken place rather rapidly the beaches would probably have experienced but little alteration, but as the water rose somewhat gradually up to the level of the new outlet those portions of the beaches exposed to wave action were reduced in height and in places almost obliterated. This makes the tracing of the Arkona beaches in southeastern Michigan rather difficult and uncertain.

Lake Whittlesey.[30] The village of Ubly, Huron County, is located upon the floor of an old drainage channel which crosses the crest of the "thumb" and leads southwestward to Cass City. This channel varies from a half to one mile in width, descends some 70 feet in its length of 22 miles and is floored with boulders and gravel (Taylor, *loc. cit.* below, p. 41). Two smaller channels enter the main one from the village of Tyre, some four miles southeast of Ubly. These channels carried the waters of Lake Whittlesey, the successor of the fluctuating Lake Arkona, into Lake Saginaw and thence by way of Grand River to Lake Chicago. The Huron and Erie ice lobes had separated from one another to a distance of about 50 miles in southern Ontario, the Huron ice front standing at the Port Huron moraine in some 150 feet of water and having a frontage of nearly 200 miles.[31] The Erie lobe probably had its apex somewhere in Ontario on a line between Port Huron and Buffalo.

30. This lake was named by Taylor for Col. Charles Whittlesey, of the early Ohio Geological Survey, an explorer of old shore lines. Correlation of Erie-Huron Beaches with Outlets and Moraines in Southeastern Michigan: Bulletin of the Geological Society of America, vol. Viii, 1897, p. 39. For description see also Leverett, Monograph XLi, U. S. Geological Survey, 1901, p. 741. Folio No. 155, U. S. Geological Survey Atlas, 1908, p. 7.
31. Taylor, The Great Ice-dams of Lake Maumee, Whittlesey and Warren: American Geologist, vol. XXIV, 1899, p. 19.

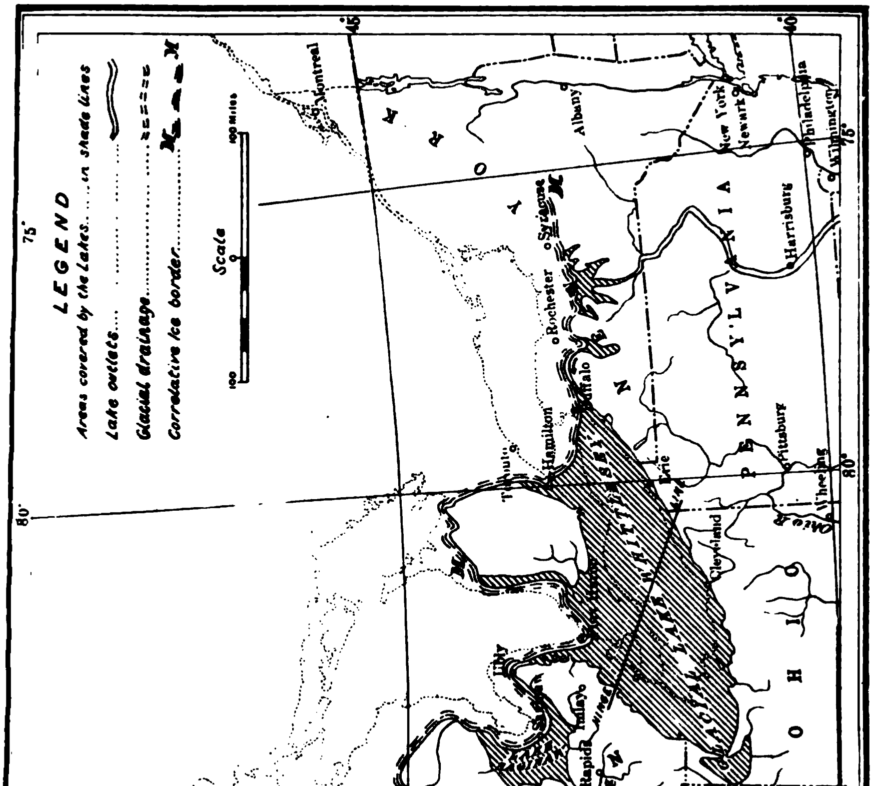

Fig. 12. Glacial Lake Whittlesey and correlatives. By Frank Leverett and Frank B. Taylor of the U. S. Geological Survey.

The lake thus impounded had approximately the form and extent shown in fig. 12, being about twice the area of Lake Erie. Its southern margin followed closely the present southern shore of Lake Erie from Buffalo to Sandusky, thence extended up the Maumee valley nearly to the Indiana line, turning abruptly to the northeast, across the northwestern corner of Wayne County and thence to the outlet at Ubly. The lake seems to have been held rather steadily at approximately the same level and for a considerable length of time, if we may judge from the development of the beach. Rather unfortunately this beach has been designated the "Belmore" from a small town in Ohio,[32] but it will simplify the study, already sufficiently complicated, and lead to no ambiguity, if we refer to it as the Whittlesey beach. As seen in southeastern Michigan it is a conspicuous gravel ridge, standing some 10 to 15 feet above the general level of the adjacent country, often deflecting the drainage streams, determining the location of the highways and furnishing an inviting site for farm buildings. It was generally recognized in an early day by the settlers, possibly also by the Indians, as marking an ancient shore line and received attention from the early Michigan and Ohio geological surveys.[33] Bela Hubbard had traced it for some 60 miles in southeastern Michigan and it was located on the map of Wayne County prepared by S. W. Higgins and published in 1840 in the Third Annual Report of State Geologist Houghton, p. 35.

In this section of the state, the elevation of the beach is now known very accurately from the work done by the U. S. topographical survey and is found to range from 735 to 740 feet above mean sea level, or say about 165 feet above the general level of Lake Erie. When traced northward it is found not to be horizontal, as we might reasonably expect it to be, but to gradually rise, and here we may stop to explain a phenomenon found in connection with the entire series of glacial lake beaches. From just beyond the "base line", the northern boundary of Wayne County, the rise is very gradual as far as Armada, in the northern part of Macomb County, amounting to about a half foot to the mile. From Armada northward to the outlet at Ubly the average rise is about three-fourths of a foot to the mile. With no recognizable tides in

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32. N. H. Winchell: Proceedings of the American Association for the Advancement of Science, Dubuque meeting; 1873, p. 177.

33. Whittlesey, Second Annual Report of the Geological Survey of Ohio, 1838, p. 55.

Hubbard, Third Annual Report of the State Geologist of Michigan, 1840. House of Representatives, document No. 8, p. 102.

A. Winchell, Geology of Washtenaw County: History of Washtenaw County, Michigan, 1881, p. 161.

An interesting historical account of the work done upon the beaches of the Great Lakes region will be found in Goldthwait's The Abandoned Shore-Lines of Eastern Wisconsin: Bulletin No. XVII, Wisconsin Geological and Natural History Survey, 1907, p. 9.

our present system of great lakes this agency may be dismissed in seeking an explanation of this anomoly. Fluctuating stages of the lake level due to wind action, or to periodicity in the amount of rainfall, would give no such gradual rise in the elevation of a single beach or in the correlative uplift of the entire series. Col. Whittlesey had noted the phenomenon in Ohio, and previous to the year 1838. Observations about the mouths of the streams entering the Great Lakes have also indicated such a movement, either a subsidence toward the southwest, an elevation toward the northeast, or a combination of the two movements, leading to what is termed a "canting" of the lake basin. In order to discover whether the lake gauges might show any evidence of such a movement still in progress, Gilbert made an investigation with rather limited and unsatisfactory data and reached the conclusion that such a movement is indicated, amounting to .42 foot (5 inches) per century in a line 100 miles long, having the bearing S. 27° W.[34] About the same time Moseley was collecting botanical data to show that the islands opposite Sandusky, Ohio, had in recent geological time been connected with the main land.[35] Later detailed studies on the sand ridges of Sandusky Bay and Cedar Point, Lake Erie, led him to conclude that the level of the water is rising at an average rate of about 2.14 feet per century,[36] presumably from this same canting effect.

Although a gradual depression of the region to the southwest would bring about the same result, the view generally held is that to the northeastward a gradual elevation is in progress, continuing a movement started just at the close of the Glacial Epoch and inaugurated very probably by the disappearance of the ice sheet from the region. If the weight of this vast mass of ice had caused a subsidence of the underlying crust, it is fair to suppose that its withdrawal would lead to at least a partial recovery of the original elevation, starting first at the southwest and proceeding gradually in the direction of ice retreat. The beaches in the southwestern portion of the Huron-Erie basin should show the least amount of differential uplift, upon this theory, and the earliest formed beaches should show more than the younger ones. Such is indeed found to be the case[37] and the theory receives correspond-

34. Gilbert. Recent Earth Movement in the Great Lakes Region: Eighteenth Annual Report of the U. S. Geological Survey, part II, 1898, p. 635.

35. . Moseley. Modification of the Great Lakes by Earth Movement: National Geographic Magazine. vol. VIII, 1897, p. 233.

36. Moseley. Formation of Sandusky Bay and Cedar Point: Presidential address, Ohio Academy of Science, vol. IV, part 5, 1904, p. 238. Abstract in Seventh Report Michigan Academy of Science, 1905, p. 38.

37. Gilbert, *loc. cit.*, page 603. Goldthwait, *loc. cit.*, page 21. See also recent paper by Hobbs, The Late Glacial and Post Glacial Uplift of the Michigan Basin: Publication 5, Geological series 3, 1911, p. 11.

ing support. This canting, or warping of the basin of the glacial lakes will be shown essential to a clear understanding of their history, amounting in some cases to as much as four to five feet to the mile in the Georgian Bay region.

An attempt has been made to account for some of this rise in the beach line by referring it to the attraction which the ice mass had for the adjacent body of water. A solution of this problem has been furnished us by Woodward, who finds that to produce an average rise in the water surface of five feet to the mile for a distance of 69 miles from the ice front would require the ice mass to be 24 miles thick about the center.[38] An ice front 10,000 feet high, exceedingly improbable during the waning stages of the ice sheet when the glacial lakes were forming, would cause an average slope towards the ice of 1.8 feet to the mile. It thus appears that the attraction of the ice for the water cannot be assumed to account entirely for the rise of the beaches toward the northeastward, although it was probably appreciable near the ice wall and should now be observed, if at all, where the beaches approach their correlative moraines.

Lake Wayne. The withdrawal of the ice entirely from the "thumb" of the Lower Peninsula of Michigan allowed the waters of the Erie-St. Clair basin to become confluent with those of Lake Saginaw, lowering the level of the combined lake some 80 to 85 feet. This lowering of the level contracted its area somewhat in Ontario, Ohio and Michigan, which loss, however, was more than compensated for by the incorporation of Lake Saginaw and the extension of the lake waters eastward into New York so as to include the Finger Lake region. The present site of Niagara was deeply buried in over 200 feet of water, drainage down the St. Lawrence being still prevented by the presence of the great ice wall. In thus falling to the lower level, the waters dropped beyond that of the next beach in the series, the Forest, or Warren beach, just as the Maumee had previously done. This was due to the temporary opening of an outlet believed to have been located just to the south of Syracuse, New York, allowing drainage into the Mohawk. In Michigan, the ice dam is believed by Taylor to have been located some 25 to 30 miles to the northeast of Bad Axe. The beach formed at this stage is very sandy in southeastern Michigan and the water line not well defined. It will be traced in some detail in the succeeding chapters. It has been generally known as the "Lower Forest" with an elevation in this region of some 655 to

38 Woodward, On the Form and Position of the Sea Level: Bulletin No. 48, U. S. Geological Survey, 1888, p. 68.

660 feet and was believed to mark the lower stage of Lake Warren. The more recent studies of Taylor have shown, however, that its level was not high enough to have permitted drainage through the Grand River outlet and in the forthcoming monograph the beach will be termed the Wayne, owing to its development at that village and the lake responsible for its formation will carry the same name. He found the evidence of submersion by the waters of the subsequent lake quite marked in the vicinity of the "thumb."

Lake Warren. A temporary advance of the ice in the region of the outlet of Lake Wayne closed that direction of escape and raised the level of the glacial waters some 25 to 30 feet, causing discharge westward by Pewamo, Ionia and Grand Rapids to Lake Chicago and thence to the Mississippi. The channel leading to Grand River is described by Taylor as 50 miles long, from three-fourths to one mile in width and descending to the southwestward at an average rate of about one foot to the mile.[39] The position of the ice dam during this stage is placed by this investigator a little to the west and south of Alpena and just south of Rochester, New York. The Erie lobe had retreated far to the northward in Ontario leaving a broad gap between the Lake Huron and Lake Ontario lobes.

The outline of this body of water is shown approximately in fig. 13 and to it the name Lake Warren has been applied by Taylor (*loc. cit.*, pp. 48 and 56.) The term "Lake Warren" had first been proposed by Spencer in 1888,[40] in honor of Gen. G. K. Warren, "the father of lacustrine geology in America," for the general expanse of waters covering the basin of the Great Lakes and believed by him to be marine in character. Used thus indefinitely and referred to later as "Warren Gulf" and "Warren Waters", it seemed desirable to restrict the name to a definite member of the series of glacial lakes. This Warren beach has an elevation of about 680 feet, is more gravelly and generally better defined than the Wayne, which is sandy and more or less obscured by wind and water action. These two beaches have been found to extend about the western and southern margins of Lake Erie, holding approximately the same interval and extending into New York, where they have been described as the "Crittenden beaches.[41] Only the lower mem-

39. Taylor, Correlation of Erie-Huron Beaches with Outlets and Moraines in Southeastern Michigan: Bulletin of the Geological Society of America, vol. VIII, 1897, p. 52.
40. Spencer, The Iroquois Beach; A Chapter in the History of Lake Ontario: Science, vol. XI, 1888, p. 49.
41. Gilbert, Surface Geology of the Maumee Valley: Geological Survey of Ohio, vol. I, 1873, p. 554.
Newberry, Geological Survey of Ohio, vol. II, 1874, p. 59.
Sherzer, Geology of Monroe County: Geological Survey of Michigan, vol. VII, 1900, p. 140.
Leverett, On the Correlation of New York Moraines with Raised Beaches of Lake Erie: American Journal of Science, vol. L., third series, 1895, p. 10.

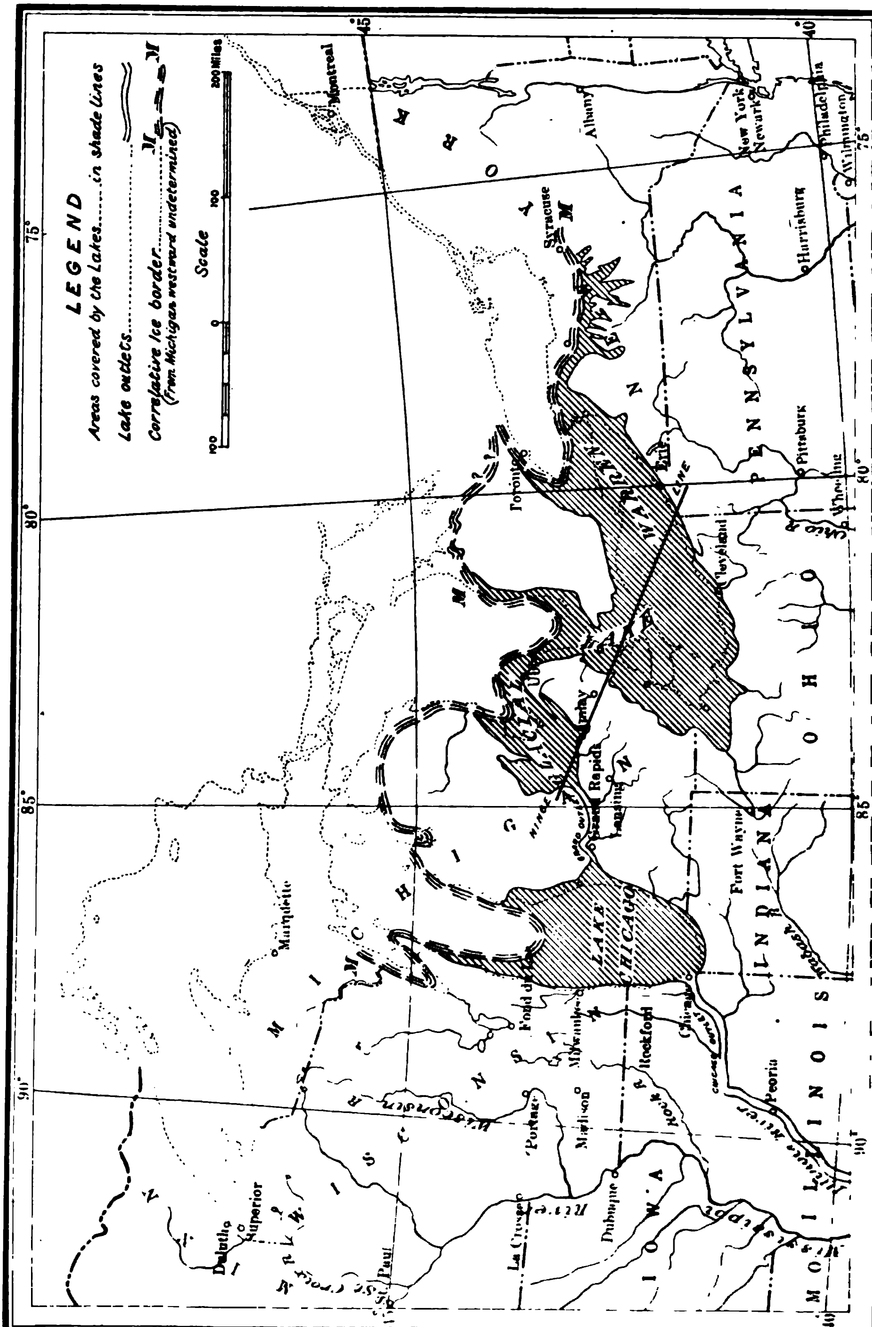

Fig. 13. Glacial Lake Warren and Lake Chicago. By Frank Leverett and Frank B. Taylor of U. S. Geological Survey.

bers of the series reach as far as Crittenden, Erie County, New York, and continue to Lima; the upper beach stopping at Alden. The interval between the Whittlesey beach (in N. Y. the "Sheridan") and the highest Warren ("Crittenden") in western New York is about 50 feet and in southeastern Michigan about 56 feet.

Lake Lundy. In a paper recently read before the Michigan Academy of Science[42] Leverett disposes under the heading "Transitional Lakes" of two stages whose beaches were described in Huron County by Lane in 1900 and the uppermost of which was recognized by the present writer in Monroe County at the same time as lying between the Forest and Algonquin beaches.[43] At this time, they were regarded as marking still lower stages of Lake Warren than those indicated by the Upper (Warren) and Lower Forest (Wayne) beaches. In Huron County, the higher was termed the "Grassmere" from the small village of that county and was found to consist of a series of ridges reaching from 672 to 692 feet above sea level. The lower was named the "Elkton" and marked a stage of the water some 25 feet lower than the lowest of the above series (647 ft. above sea level, in Huron County). In Wayne County, two belts of sand dunes and ridges mark the location of these two beaches at elevations of 635-640 and 610-615 feet respectively, the differential uplift to the north accounting for the higher elevation of the beaches in Huron County. Wind action has apparently obliterated the triple character of the Grassmere, in case it was originally present. The vertical interval from the Wayne to the Grassmere is about 20-25 feet in Wayne County while in Huron County it measures 70 to 75 feet, apparently indicating that between the formation of these two beaches there was a time interval sufficient to allow a deformation of some 50 feet to take place.

These beaches have not been followed continuously to their outlets and correlative moraines and hence our knowledge of the lakes producing them is of a very indefinite character. Lane in his paper, previously referred to, included the Grassmere beaches with the Lake Warren series[44] and the Elkton beach with a lake of the Finger Lake region of New York, described by Fairchild and named Lake Dana.[45] The latest disposition of these two beaches is

42. Presidential address; Outline of the History of the Great Lakes: Twelfth Report, 1910, p. 34.
43. Lane, Geological Report on Huron County: Geological Survey of Michigan, vol. VII, pt. II, 1900, p. 74.
Sherzer, Geological Report on Monroe County: Same volume, p. 141.
44. Geological Survey of Michigan, Report for 1907, p. 130.
45. Fairchild, Glacial Waters in the Finger Lakes Region of New York: Bulletin of the Geological Society of America, vol. X, 1899, p. 56. See also American Journal of Science, Fourth Series, vol. VII, 1899, p. 260.

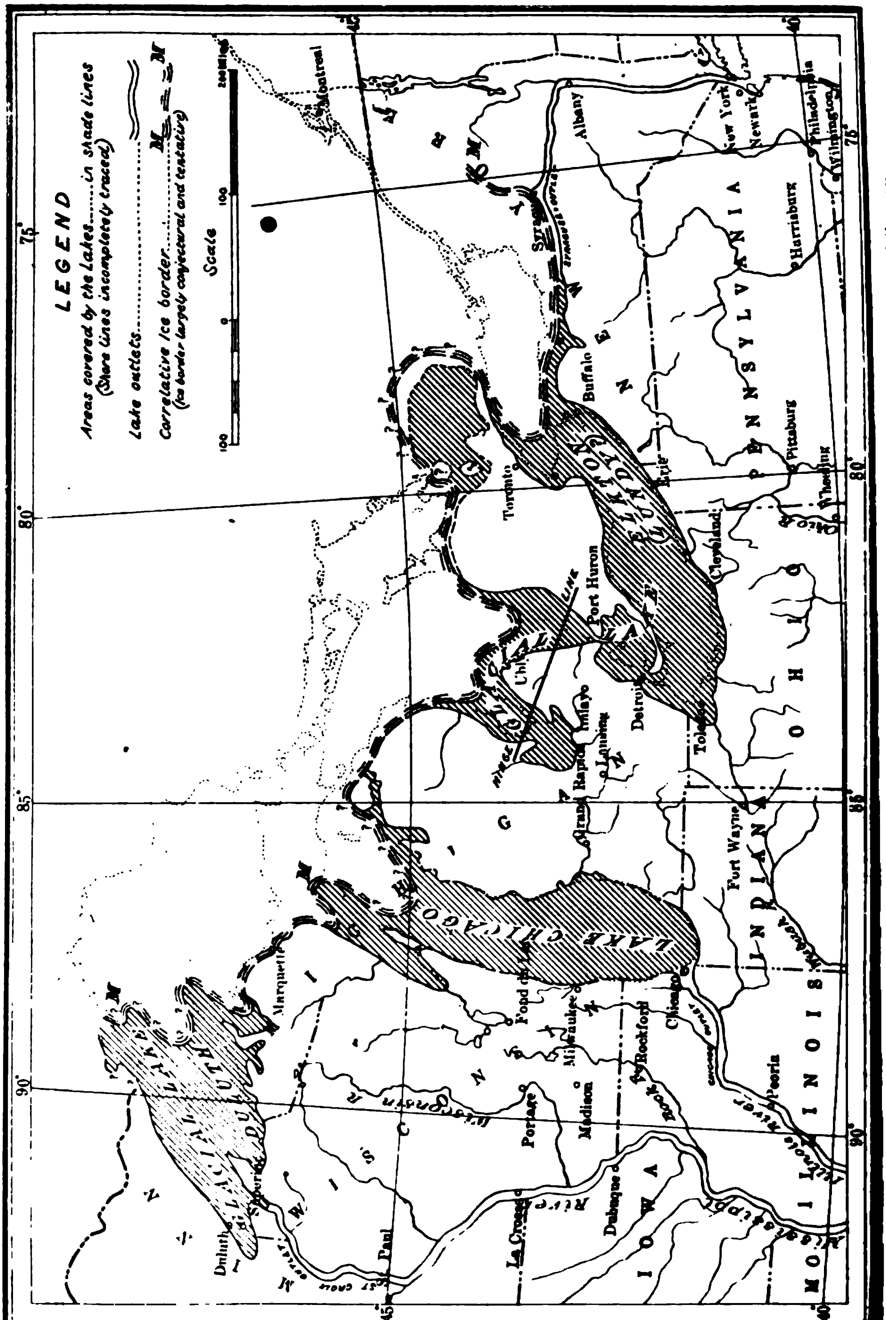

Fig. 14. Glacial Lake Lundy and correlatives. By Frank Leverett and Frank B. Taylor of U. S. Geological Survey.

by Taylor who regards this lake as the western extension of Spencer's Lake Lundy of western New York and southern Ontario, the two stages of which we may recognize as the Grassmere and Elkton (See fig. 14).

Lake Algonquin. The withdrawal of the ice from the Straits of Mackinac to an unknown distance into Canada allowed the waters that had been accumulating in the basins of the three upper lakes to become confluent and a single vast water expanse resulted, known as Lake Algonquin.[46] This lake had a complicated history, the full discussion of which has been prepared by Taylor for the monograph previously cited. Starting with a theoretical stage covering the southern half of Lake Huron and draining southward by the St. Clair outlet, with the ice front near Alpena, Michigan, and Port Elgin, Ontario, the waters extended themselves into the basins of the three upper lakes. The withdrawal of the ice to the northeastward opened a passage way through the Trent River valley, at Kirkfield, Ontario, into Lake Iroquois, the predecessor of Lake Ontario.[47] The studies of Goldthwait in 1905 showed that the highest beach of Lake Algonquin in the Lake Michigan region skirts the head of the lake as the "Toleston beach,[48] which indicates that the lake, at its highest stage, made use of the old drainage channel of glacial Lake Chicago into Illinois River and thence to the Mississippi. The sill of this old outlet has an elevation now of eight feet above the present level of Lake Michigan, or about 590 feet above sea level. The use of these three outlets;— St. Clair, Chicago and Trent, conjointly, or separately, rendered possible a very complicated history, the stages of which may eventually need to be distinguished by separate names. Sometime during the early life of the lake the Mohawk valley became clear of ice sufficiently to allow the waters of the Ontario basin to drop, causing the separation of Lakes Erie and Iroquois and giving birth to Niagara. The presence of abundant molluscan life in Lake Algonquin is indicated by shell remains in the beach deposits, reported from several localities, and suggests that the waters were no longer of glacial temperature.[49] This change in temperature was ap-

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46. This name was proposed by Spencer in 1888 for the lake, the beach and the river by which the lake was drained through the Trent valley, Ontario. Notes on the Origin and History of the Great Lakes of North America: American Association for the Advancement of Science, vol. XXXVII, 1889, p. 199.

47. Gilbert, The Algonquin River: American Geologist, vol. XVIII, p. 231.

48. Goldthwait, The Abandoned Shore-Lines of Eastern Wisconsin: Wisconsin Geological and Natural History Survey, Bulletin No. XVII, 1907, page 42. Leverett, Chicago Academy of Sciences: Bulletin No. II, 1897, p. 74.

49. Marcy, Geological Survey of Illinois, vol. III, Geology and Paleontology, 1868, p 250.
Alden, Chicago Folio, No. 81, U. S. Geological Survey, 1902, p. 10.
Lane, Geological Survey of Michigan, vol. VII, 1900, p. 248.
Goldthwait, Bulletin No. XVII, Wisconsin Geological Survey, 1907, p. 118.
Leverett, Chicago Academy of Sciences, Bulletin No. II, 1897, p. 77.

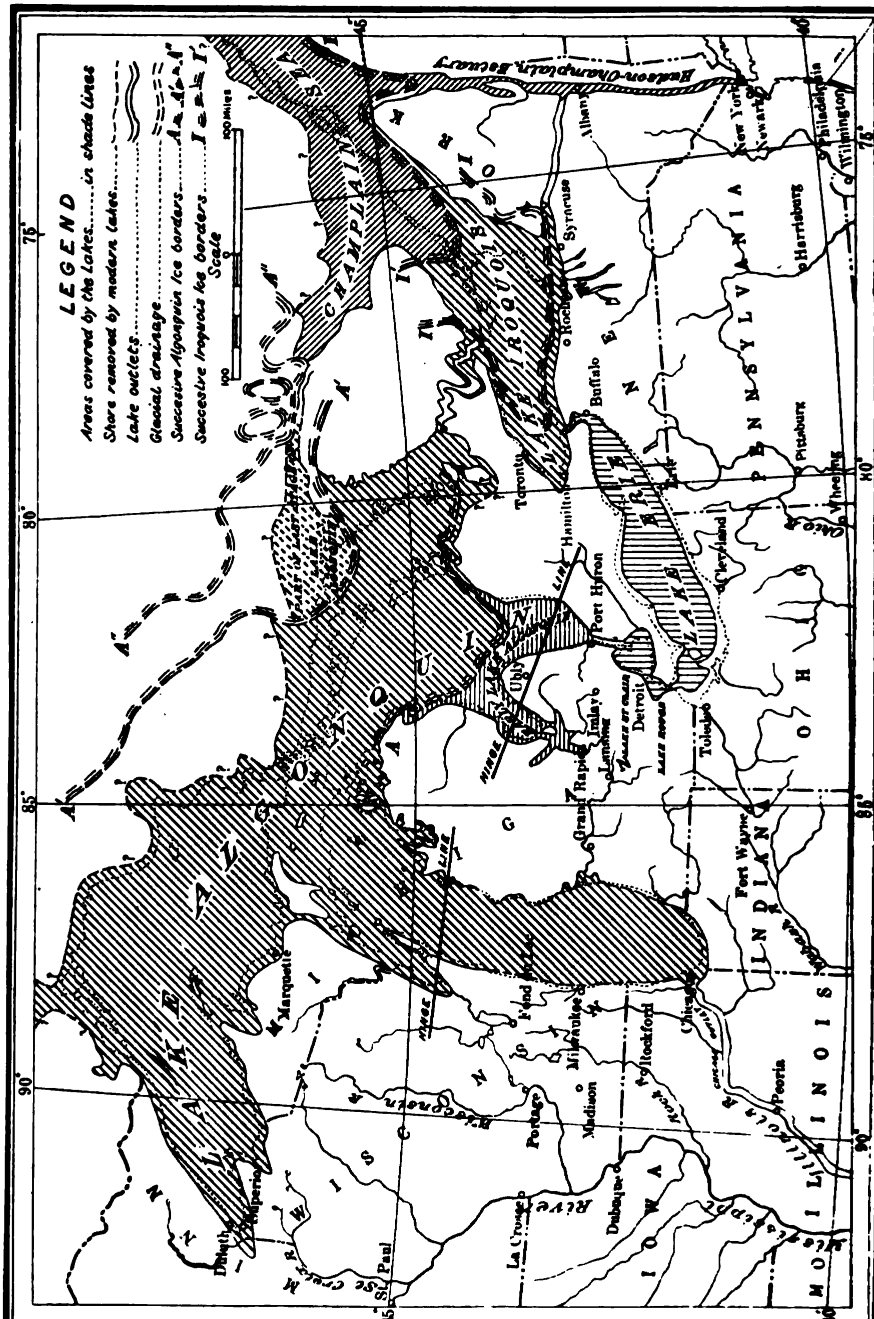

Fig. 15. Glacial Lake Algonquin and correlatives. By Frank Leverett and Frank B. Taylor of U. S. Geological Survey.

parently due to the reduction of ice frontage as the ice wall withdrew into the Mattawa and Ottawa valleys of the Georgian Bay region. One stage of Algonquin history is shown in fig. 15 during the life of the Trent and St. Clair outlets.

The differential uplift to the northeastward, to which previous allusion has been made, is believed to have been responsible for the elevation of the bed of the Trent outlet sufficiently to cause the waters to escape southward at the present site of Port Huron, through the St. Clair and Detroit valleys into Lake Erie. It has been suggested that both the Chicago and St. Clair outlets may have served at the same time, supposing that Lake Iroquois was then in existence. Lake Erie was deprived of the drainage from the three upper lake basins, was considerably smaller than at present (elevation 560 feet), but the beaches then made by which its size and depth could be determined are now submerged by its own waters. St. Clair and Detroit rivers carried simply the water from their own, comparatively small, drainage basins and were correspondingly reduced in size. Their tributaries flowing to this lower level cut channels considerably below what is now the normal depth for these streams. Since Lake Algonquin did not reach as far south as Wayne County only its correlative beaches are there represented, encircling the present margin of Lake St. Clair and that of the extinct Lake Rouge (see below). These are the bodies of water through which the Algonquin drainage took place during certain stages and hence they stand at a somewhat lower level, about 590 feet above tide, or 15 feet above the present water level. Owing to the relatively limited size of these bodies of water and the consequent weak wave action, these correlative beaches, to be termed by Taylor the First St. Clair and First Rouge, respectively, are generally poorly defined. In places a slight cut in the clay, or a faint gravel ridge is all that marks the former water line.

Lake Rouge. During the later phase of Lake Algonquin and simultaneously with the existence of First Lake St. Clair, there was an embayment of water covering the lower Rouge basin to which the name "Lake Rouge" will be given by Mr. Taylor in a forthcoming monograph of the U. S. Geological Survey (The Pleistocene of Indiana and Michigan) now in preparation by Messrs. Taylor and Leverett.[50] This lake covered the present site of the

50. Through the kindness of these authors, the writer has had access to those portions of their manuscript dealing with the physical features of southeastern Michigan and has had the benefit of their personal explanations and advice. The lake stages reproduced in this chapter are also from this source and here used through the courtesy of the U. S. Geological Survey.

Woodmere and Delray additions to the city of Detroit, the southern half of Springwells township, the eastern two-thirds of Ecorse and the northern point of Grosse Isle. In Essex County, Ontario, it extended some one to four miles east from the river, the heavy sands obscuring the features of the Grosse Isle moraine described later. The lake was some 10 to 12 miles in length and 8 to 9 miles broad, the upper beach standing from 588 to 590 above sea level, but with sand ridges rising to 595. The lake was a shallow one and the bottom was subjected to wave action throughout the greater part of its extent. The lower, or Second Rouge beach, was formed during the life of Lakes Nipissing at an elevation of 580 to 582 feet above sea level. In places it is represented by a well defined sand ridge, again as a cut terrace, but owing to recent steam action can not be continuously traced.

Nipissing Great Lakes. Modern Lake Nipissing lies in an east and west trough, leading across the highlands north of Georgian Bay to the valleys of the Mattawa and Ottawa rivers in Ontario. Here a comparatively narrow ice dam had sufficed to hold back the waters of Lake Algonquin for many centuries. Finally a weakening of the ice along the southern margin of the valley allowed some of the water to escape and the level was gradually lowered, with halts sufficiently long to permit the formation of a succession of weak beaches. At first, the discharge from the receding lake was through both outlets, but was gradually shifted to the Nipissing, and thence through the Mattawa and Ottawa valleys to an arm of the ocean (Champlain Sea) then covering the Ontario and St. Lawrence basins. When the ice and its deposits had been cleared away the cutting down of the outlet was very slow and the water level was fairly constant for a relatively long period, so far as may be judged from the strength of the beach formed. The lake at this stage occupied the basins of the three upper Great Lakes (Superior, Michigan and Huron), reaching slightly beyond their present limits, as is shown in fig. 16. To this body of water, already differentiated into our present lakes, and their immediate predecessor, Taylor gave the name Nipissing Great Lakes.[51]

The gradual differential uplift to the northeastward slowly brought the Nipissing outlet to the approximate level of the bed of the St. Clair and drainage through both outlets is believed to have taken place for a considerable time. Finally the drainage was completely shifted to the St. Clair-Detroit outlet, into Lake Erie, and lakes Huron, Michigan and Superior may be said to have

51. A short History of the Great Lakes: Studies in Indiana Geography, first series, 1897, p. 105. See also The Second Lake Algonquin: American Geologist, vol. XV, 1895, p. 100.

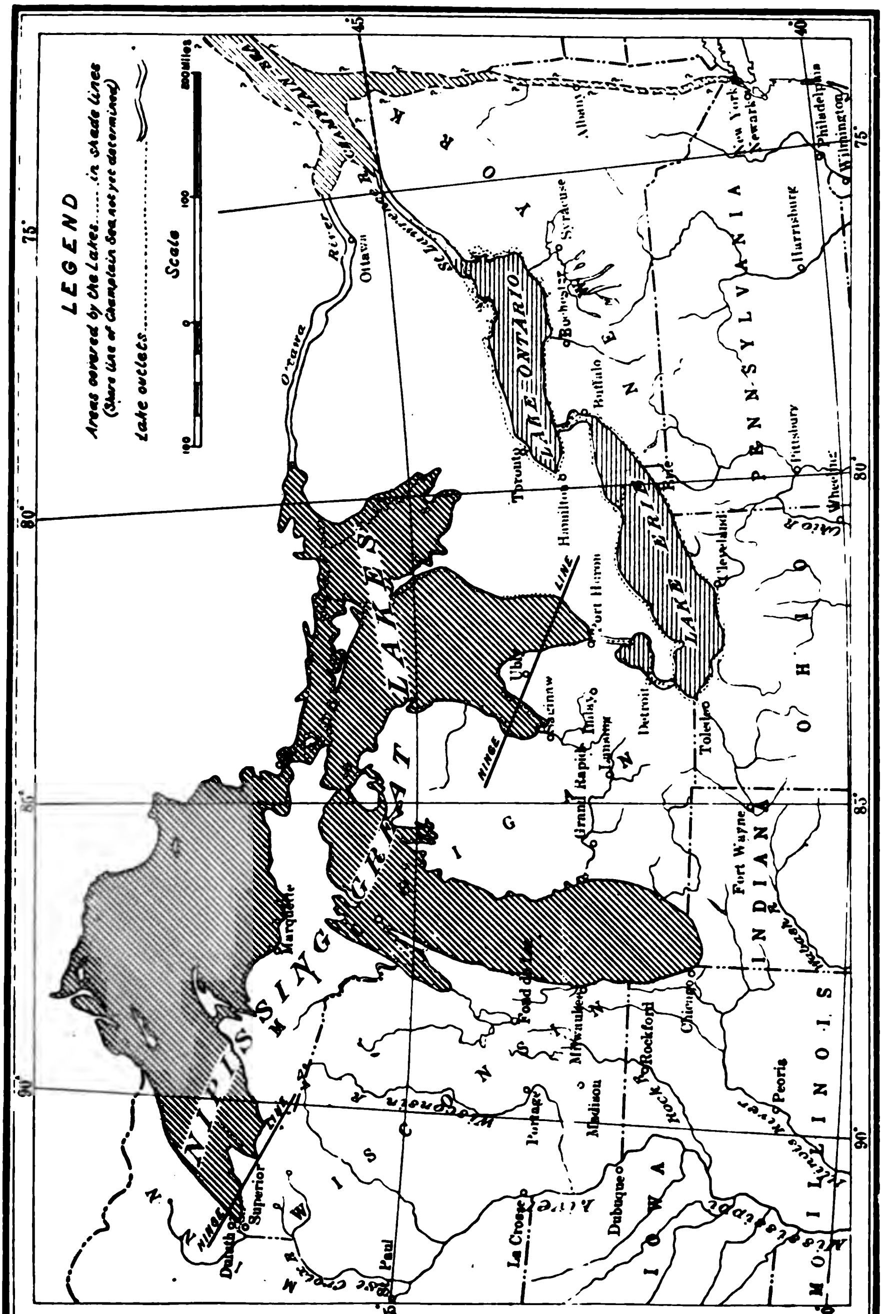

Fig. 16. Nipissing Great Lakes and correlative marine waters. By Frank Leverett and Frank B. Taylor of U. S. Geological Survey.

come into existence. The northeastward uplift has continued until the old Nipissing outlet now stands about 100 feet higher than when it was abandoned, giving the beaches a gradual tilt in that direction. As previously noted the correlatives of the Nipissing beaches are represented in Wayne County by the Second St. Clair and Second Rouge beaches, some 6 to 7 feet above the present level. They consist in places of a cut bench close to the present water line or of a sand ridge, removed to a greater or less distance by the surface slope.

Time estimates. Reference has been made to the relative time involved in the various lake stages described in this chapter and every student of the subject grasps eagerly at any opportunity offered to translate this time into actual years. Based upon the amount of cutting done by the waters of Niagara since it came into existence, various observers have made estimates of the time that has elapsed since the waters of the Ontario basin separated from those of the Erie basin.[52] There are so many factors of uncertainty, however, that these estimates are at wide variance with one another. Chamberlin and Salisbury give 25,000 years as the mean of all such estimates.[53] Leverett considers that the time can not be less than 15,000 years and may as great as 30,000.[54] Based upon the amount of weathering that has taken place along the walls of the gorge of Niagara, Wright has made an estimate of its age independently of the rate of stream erosion and places this at 10,000 years.[55] These estimates, it should be noted, cover the time that has elapsed since the early life of Lake Algonquin. In order to reach back to the beginning of Lake Maumee, they should probably be doubled.

In his report on Huron County (*loc. cit.*, 1900, p. 79), Lane has furnished us an estimate of the time involved in this lake history since the birth of Lake Warren, based upon the volume of the beaches and dunes derived therefrom and upon the amount of cutting of the land by the waves during the various stages. He considers that some 4,000 years have elapsed since Lake Algonquin came into existence and that the wave action since more than equals that which preceded. If we note that the amount of such action, in a given time, would be considerably greater in the more expanded, later lakes than in the earlier, smaller ones we may double this estimate of 4,000 years, and perhaps extend it to 10,000.

52. Wright, Ice Age in North America, 1889, p. 448.
53. Geology, vol. III, 1906, p. 419.
54. Twelfth Report of the Michigan Academy of Science, 1910, p. 40.
55. New Method of Estimating the Age of Niagara Falls: Popular Science Monthly, vol. LV, 1899, p. 145.

Some 30 years earlier than this work of Lane's, Andrews had similarly based time estimates of the beaches about the head of Lake Michigan upon the action, both destructive and constructive, now taking place at the present level.[56] His estimate is some 6,000 years since Lake Chicago came into existence, one-half of which is to be assigned to the present Lake Michigan. Since Lake Chicago was the contemporary of Lake Maumee, this estimate would apply also to the series of glacial lakes of the Huron-Erie basin. Lane calls attention to the fact that since the Nipissing beach is not represented in the region studied by Andrews his estimate of 6,000 years would need to be considerably extended.

Still another method of gaining some idea of the length of time involved in this geologically recent history of this region may be based upon the rate of uplift now believed to be in progress. Lane has estimated that if this rate has been continuous for a sufficient time, to bring the present water-plane up to that now indicated by the Nipissing beach would require about 14,000 years.[57] It is very probable, however, that the rate of uplift was considerably more rapid as we pass back to the time when the ice was just withdrawing from the region and that any estimates based upon the present, supposed rate of uplift would need to be considerably reduced. This discussion is sufficient to show the reader that the factors involved in all such estimates are as yet very uncertain quantities, but that the glacial lake history is to be reckoned in *thousands* of years, rather than centuries and that it may fall within the period of human occupancy of the continent.

If estimates of the age of the series of glacial lakes are found to be so divergent and uncertain, still more so will be those formulated to express the ages of the various ice sheets themselves. Consequently, these data will need to be expressed in hundred-thousands of years, instead of simple thousands, and they are founded upon the relative amount of stream and atmospheric erosion, combined with weathering and leaching, that has affected the surfaces of the various till-sheets in those regions where they were not covered or modified by subsequent ice invasions. From an intimate acquaintance with the various areas suitable for such comparative study, Leverett has estimated that in the case of the Late Wisconsin fully nine-tenths of the till plains still stand at the original level,[58] while, in the case of the Illinoian, only one-half

56. The North American Lakes Considered as Chronometers of Post Glacial Time: Transactions of the Chicago Academy of Sciences, vol. II, 1870, pp. 1 to 23. See also American Journal of Science, vol. XCVIII, 1864, p. 172.
57. Huron County report; *loc. cit.*, 1900, p. 84.
58. Leverett. Weathering and Erosion as Time Measures: American Journal of Science, vol. XXVII, 1909, p. 354.

remains. The Kansan till-sheet, produced by one of the great movements from the Keewatin center, is similarly estimated to have only *one-tenth* of the original glacial deposit left at the original level. Bain has estimated that the capacity of the post-Kansan valleys in Iowa is 10 to 15 times greater than that of the post-Wisconsin valleys,[59] and apparently nearer the larger figure. In 1896 Chamberlin, after consultation with various individuals familiar with the field phenomena, made up a table showing the age ratios of the various glacial stages then recognized. Calling the time interval unity that has elapsed since the culmination of the Late Wisconsin, the age of the Early Wisconsin is expressed by 2½; the Iowan by 5; Illinoian 7 and Kansan 15.[60] The latest contribution to this discussion has recently been made by Leverett and presented to his class in glacial geology at the University of Michigan (1909). Taking 25,000 years as a fair estimate of the time involved in the formation of the gorge of Niagara he constructs the following table.[61]

TABLE VII.—ESTIMATED AGE OF GLACIAL EPISODES (LEVERETT).

	Years.
Culmination of Late Wisconsin	50,000
Culmination of Early Wisconsin	100,000
Beginning of Wisconsin	150,000
Culmination of Illinoian	300,000
Beginning of Illinoian	350,000
Culmination of Kansan	750,000
Beginning of Kansan	800,000
Culmination of pre-Kansan (Nebraska)	950,000
Beginning of pre-Kansan	1,000,000

The chief value of such a table is to convey to the reader the probable great age of this geologically recent episode in our earth's history and to furnish a basis for the comprehension of the relative times at which the various events occurred.

59. Bain, Relations of the Wisconsin and Kansan Drift Sheets in Central Iowa, and Related Phenomena: Iowa Geological Survey, vol. VI, 1897, p. 474.
60. Chamberlin, Journal of Geology, vol. IV, 1896, p. 876.
Table of estimates slightly revised, Chamberlin and Salisbury's Geology, vol. III, 1906, p. 414.
61. See also table given by Chamberlin and Salisbury in Geology, vol. III, 1906, p. 420.

TABLE VIII.—GLACIAL LAKES OF THE HURON-ERIE BASIN.—(BASED UPON A TABLE PREPARED BY FRANK B. TAYLOR, MARCH, 1913.)

Name of lake.	No. of stages.	Names of beaches.	Elevation of beach south of "hinge line."	Location of ice dam.	Location of outlet.	Location of beach in Wayne County.
Maumee...	3	Highest or Van Wert....	800 to 812	Defiance and Birmingham moraines. Scofield boulder belt.	Ft. Wayne channel.	Series ,crowded together between Plymouth and Waterford.
		Middle or Leipsic.......	775 to 785	Imlay to Yale moraines.	Mainly Imlay channel, also Ft. Wayne.	
		Lowest................	770 ±	Unknown..	Probably north of Imlay City.	
Arkona....	3–4	Highest...............	708 to 710	Some 25 miles to the northeast of Bad Axe.	All stages by Grand River channel.	Denton and Nankin.
		Middle................	698 to 702			
		Lowest................	690 to 694			
Whittlesey.	1	Whittlesey or Belmore....	735 to 740	Port Huron moraine.	Ubly channel to Lake Saginaw.	Plymouth.
Wayne....	1	Wayne or Lower Forest...	650 to 657	Nearly same as for Arkona.	Probably south of Syracuse, N. Y.	Romulus, Wayne, Livonia.
Warren....	1	Warren or Upper Forest..	675 to 680	Somewhat to the west and south of Alpena.	Grand River channel to Lake Chicago.	Canton.
Lundy....	2	Grassmere.............	635 to 640	Slightly farther north than for Warren.	Probably south of Syracuse, N. Y.	New Boston, Sand Hill, Highland Park. Hand, Dearborn, North Detroit.
		Elkton................	615 to 620			
Algonquin.	4	Early Algonquin........	607 ±	Across bed of Lake Huron north of "thumb."	Port Huron outlet.	Not recognizable.
		Main or Upper.........	603 to 607	Superior, Huron and Georgian Bay.	Kirkfield, Ont., Port Huron and Chicago.	Correlative only, shown by the First St. Clair and First Rouge.
		Battlefield.............	?	Same but farther north.	Port Huron mainly, also Chicago.	
		Ft. Brady.............	?	Northeast of Georgian Bay.	Same as for Battlefield.	
Nipissing..	2	Nipissing, one-outlet.....	?	No ice dam for either stage.	North Bay, Ont.	Correlative shown in Second St. Clair and Second Rouge, skirting present shore line.
		Nipissing, two-outlets....	596		North Bay and Port Huron.	
St. Clair...	2	First St. Clair..........	593	Same as main Algonquin.	Upper early Detroit River.	St. Clair Heights.
		Second St. Clair........	582	No ice dam.	Next stage upper Detroit River.	Milk River Point, Cottage Grove, Fairview.
Rouge	2	First Rouge...........	593	Same as main Algonquin.	Lower early Detroit River.	Flat Rock, Wyandotte Heights, Woodmere Cemetery.
		Second Rouge..........	582	No ice dam.	Next stage lower Detroit River.	Ft. Wayne, Brady Island, River Rouge.

CHAPTER III.

PHYSICAL GEOGRAPHY OF WAYNE COUNTY.

SURFACE CONFIGURATION.

General topography. The surface features of Wayne County readily fall into two main divisions, easily distinguished and clearly understood in the light of its recent geological history. There is first the rough, morainic area covering only the northwestern corner of the county and the broad, flat lake plain; which, were it not for subsequent stream, wave and wind action would appear remarkably even. As noted by Hubbard in his early geological report, the dividing line between these two areas is the Whittlesey beach, the location of which was determined by the eastern slope of the morainic area itself while the waters of this and the subsequent lakes subdued any elevations that may have been left by the ice sheet and filled in with clay or sand any depressions. Between the Whittlesey and Upper Maumee beaches there is an intermediate strip, quite narrow in Wayne County, but broadening to the southwestward, which partakes somewhat of the character of either main area. Throughout this strip the morainic knolls were originally low, the depressions shallow and wave action and deposition slight although plainly noticeable when looked for. Along the entire eastern margin of the county, morainic features may also be detected but they are more or less obscured and disguised, owing to the conditions of their formation and subsequent history, and they blend very naturally with the features of the lake plain itself.

The highest point noted in the county by the U. S. Topographic Survey is the extreme northwestern corner, 975 feet above sea level, or 400 feet above the ordinary level of Detroit River at Detroit. A few hundred yards to the southeastward a slightly higher ridge places the county below the plane of vision and serves as a narrow water-shed for the surface drainage of this region. The general slope from this level is southeastward and averages about 16 feet to the mile, but from the base of the inner slope of the Whittlesey beach to the river level is only one-half this amount, or but 8 feet to the mile, a slope imperceptible to the eye. This slope of the

surface of the till imparted to the streams of the county their general southeasterly direction, gave the beaches their northeast-southwest trend and, as will be pointed out later, projected itself forcibly into the subsequent history of the region.

Moraines and boulder belts. If one stands on the "base line", at this extreme northwestern corner of the county, where by moving a step he may bring himself into Wayne, Washtenaw or Oakland counties, and casts his eye from north around to the southwest he notes an elevated tract made up of numerous knolls and ridges, extending in a northeast-southwest direction across Oakland and Washtenaw counties. Although he is now on a relatively level gravel and sand tract, nearly a thousand feet above the sea, broad knolls to the north and west may be seen from one-half mile to two miles distant rising to an additional height of 150 feet. To the northeastward this rough belt of country extends into St. Clair and Sanilac counties and in the opposite direction into Ohio and Indiana and constitutes the Ft. Wayne moraine. It was formed by the Late Wisconsin ice sheet, during a temporary halt of the ice front, when the Huron-Erie lobe of ice completely covered the county of Wayne as a broad tongue with a northeast-southwest axis. Historically, this moraine is of interest since it was one of the first to be recognized in the country, being described by Gilbert in 1871.[1] Owing to its relation to the St. Mary's River, in Ohio, it was named the "St. Mary's ridge"[2] and because of its subdued character in that region was believed to represent a moraine buried in lake clays. This moraine is figured by Chamberlin in his paper the Terminal Moraine of the Second Glacial Epoch,[3] but is there undescribed and unnamed.* The term "Ft. Wayne" was first applied to it by Taylor in 1897 in a paper entitled "Moraines of Recession and their Significance in Glacial Theory" (Journal of Geology, vol. V, p. 433). A description of that portion lying in Ohio and Indiana will be found in Leverett's Monograph (No. XLI) of the U. S. Geological Survey[4] and a further description of the Michigan portion of this moraine has been prepared by Leverett and Taylor for a forthcoming monograph on the glacial features of southern Michigan. The crest of this moraine in Washte-

1. Gilbert, On certain Glacial and Post-glacial phenomena of the Maumee Valley: American Journal of Science and Arts, Vol. I, 3rd series, 1871, p. 340. Also Geological Survey of Ohio, Vol. I, 1873, p. 540.
2. N. H. Winchell, The Surface Geology of Northwestern Ohio: Proceedings of the American Association for the Advancement of Science; Dubuque meeting, 1873, p. 168. By Dryer in 1889, it was referred to as the "St. Mary's and St. Joseph Moraine:" Sixteenth Annual Report of the Department of Geology and Natural History of Indiana, p. 114.
3. Third Annual Report of the Director of the U. S. Geological Survey, 1883, pl. XXXI.
4. Glacial Formations and Drainage Features of the Erie and Ohio Basins, 1902, pp. 566 to 578. See Also Ann Arbor Folio, No. 155, U. S. Geological Survey, 1908, p. 6.

naw and Oakland counties forms the water-shed between the basins of the upper Huron and Rouge rivers.

The ice sheet finally withdrew from the Ft. Wayne moraine, uncovering the extreme northwestern corner of the county and making a comparatively brief halt. The ice margin fluctuated over a strip about a mile broad, pushing up ridges and knolls, separated by sags and "kettle-holes", the general course of which was parallel with the previously formed moraine. In places, the glacial drainage streams left the ice under "head" and the sand and gravel carried by these torrents built up knolls and ridges of irregularly stratified deposits of these materials about the margins of the ice, partly beneath and in the reëntrant angles of the irregular ice front. These deposits are known as *kames* and they are so numerous in secs. 4, 5, 6 and 7 of Northville township as to constitute a "kame-moraine", a term suggested by Salisbury for similar moraines seen in New Jersey.[5] A detailed study of 2,000 pebbles from the kames of northwestern Wayne and the adjacent portion of Oakland county indicates that from 40 to 50% of them are limestone or dolomite and but about 19% are of the crystalline type. This indicates that the supply of rock fragments for these kames was derived, in the main, from the till deposits rather than from the ice itself and suggests that the streams were of the subglacial type, instead of being englacial, or supraglacial. Of the 1,000 pebbles from a single kame, the property of the Detroit United Railway, at Northville, 506 were calcareous, of which 216 (43%) were limestone and 290 (57%) were dolomite. About 1 7 of the pebbles were found to be quartzite (15%) and about the same (13%) proved to be chert, derived originally from calcareous strata. The subangular to rounded condition of these pebbles, when compared with those from the till, indicates that they have been subjected to considerable stream action by the glacial currents. Owing to its position between the Ft. Wayne and Defiance moraines and its apparent distinctness from either in this region, this moraine was referred to by Leverett in the Ann Arbor Folio (p. 6) as the "middle moraine" but may best be designated as the Northville from its relation to that village. Southwestward towards Ann Arbor, it unites with the Ft. Wayne, indicating little or no retreat of the ice front here from its former position. From Ann Arbor southward, it is distinct from the Ft. Wayne but becomes united with the Defiance and indistinguishable from it. The roughest portion of this moraine in Wayne County is found in

5. Report of the State Geologist of New Jersey for 1892, p. 93. The Glacial Geology of New Jersey, 1902 p. 117.

section 5 of Northville, where the knolls rise to 940 and 960 feet above sea level. Boulders are scattered sparingly over the surface of the moraine where they were dropped as the ice melted from beneath them.

After another slightly more pronounced retreat of the ice front to the southeast and a fluctuating halt, there was formed the Defiance moraine, a belt two to three miles broad of knolls and irregularly disposed ridges, mostly of till but occasionally also of gravel and sand, having a northeast and southwest course across Canton, Plymouth and Northville townships. The knolls rise to a height of 840 to 860 feet very generally but reach the 900 foot contour in SE. ¼ sec. 11 and 920 in the NW. ¼ sec. 16, Northville township (see Pl. X). Toward the northeastward, this moraine extends parallel with those previously formed, curving to the northward and then westward in Lapeer County. In the opposite direction, it stretches across Washtenaw and Lenawee counties, curving to the southward and eastward in the Maumee valley. This portion was first figured by Gilbert in 1871, at the time of the mapping of the Ft. Wayne moraine, and it was then regarded as a terminal moraine deeply buried in lake clay.[6] Although Gilbert assigned no name to it the name "Blanchard Ridge" was used by N. H. Winchell in his paper upon "The Surface Geology of North-Western Ohio" (*loc. cit.*, p. 175) this name being derived from one of the streams, the course of which it governs. This name was subsequently changed to "Defiance", from the name of the city located thereon.[7] Where the moraine is crossed by the Pere Marquette Ry., west of Plymouth, the profile shows a ridge crest in the NW. ¼ sec. 20, at an elevation of 852 feet, a sharper and higher crest (862 feet) lying 1,100 feet to the eastward, with the bottom of the sag 837 feet. In the SE. ¼ sec. 20, there occurs the highest crest (866 feet) along the line of the railway. Along the eastern slope of the moraine, into section 21, the fall is rather rapid, dropping below the 800 foot contour, rising to 834 feet in SE. ¼ sec. 21, showing three minor ridges and dropping to the level of the Maumee beaches in SW. ¼ sec. 22, Plymouth.

The steepest slope is upon the eastern side of the moraine from the 800 to the 760-foot contour and this strip is dissected by short, parallel streams and was considerably eroded by the waves of the Maumee lakes. Between the Upper Maumee beach (812 feet) and that of Lake Whittlesey (736 feet), the morainic ridges and

6. On certain Glacial and Post-Glacial phenomena of the Maumee Valley: American Journal of Science and Arts, third series, vol. I, 1871, p. 341. See also Geological Survey of Ohio, vol. I, 1873, p. 542.
7. Leverett, Monograph XLI, U. S. Geological Survey, 1901, p. 581.

mounds gradually die out, some of them exhibiting signs of wave cutting while submerged in Lake Maumee. Throughout this morainic surface boulders are rather sparingly displayed, and none of considerable size were observed. The wells on the moraine are too shallow to reach bedrock, or reliance is had upon the numerous springs of the region so that the actual thickness of the morainic deposit is unknown. The nearest records are from Plymouth and Northville and indicate a probable thickness of 150 to 250 feet.

Subsequent to the formation of the Defiance moraine just described the ice front withdrew for a distance of one to ten miles. shortly beyond the present sites of Plymouth and Denton, and there appears to have made a quiet and relatively brief halt, depositing a line of cobbles and boulders which can be traced continuously across the NW. ¼ Livonia, the SE. corner of Plymouth and southward across the center of Canton and Van Buren townships to Belleville. Here the course appears to be westward, parallel to the river, crossing it at Rawsonville, where the boulders have been concentrated by stream action, as noted in 1838 in the field notes of Hubbard. The boulder belt continues westward into Washtenaw County and appears to join the Defiance moraine in the southwestern corner of Ypsilanti township. From Belleville westward the surface boulders have been largely obscured by subsequent delta deposits and are seen mainly in the valley of the Huron and its short tributaries. In Livonia and Plymouth townships the boulder belt lies between the 700 and 720-foot contours, dropping in Canton township to the interval between the 700 and 680 foot contours and again rising to the former level as the belt passes into Washtenaw County (see Pl. X). In many places along this boulder belt, the rock fragments have been collected and utilized for foundations and, as this goes on, traces of this stage of halt of the ice will be gradually obliterated. At only a few places were they originally abundant enough to be obtrusive. It may appropriately be designated the "Rawsonville boulder belt" to distinguish it from the two subsequently formed.

A second boulder belt, apparently entirely independent of any of the previously described moraines, has been traced by the writer across Wayne, Monroe and Lenawee counties into Ohio (Pl. X), and believed by the writer to indicate another stage of halt of the

ice margin in its retreat from the western to the eastern part of the county. From the village in Monroe County near which it passes, this may be distinguished as the "Scofield boulder belt". The halt seems to have been accompanied by no minor advances in Wayne and Monroe counties whereby a set of ridges might have been produced in the underlying ground-moraine and the rock fragments embedded in the ice, or resting on its surface, were brought to the margin and there dropped. Granting that these were fairly abundant, the time involved in the halt may have been short, but if we may judge of their abundance by the number present in the next older (Defiance) and next younger Grosse Isle moraines, the time allowed for the formation of the boulder belt must be correspondingly increased. The boulders consist of subangular fragments of granites, gneisses, schists, greenstones, conglomerates and quartzites. Limestones are rare and sandstones and argillites still more so. Only occasionally is one found with traces of glaciation, quite in contrast with the rock fragments of the till.

The belt is a narrow one, from one to two miles broad and, in places, is completely obscured by subsequent deposits of beach and delta sands and gravel. It is less well defined, where it enters Wayne from Oakland County, crossing Livonia and Nankin townships somewhat eastward of the central meridian. In sec. 15 of Livonia, the boulders and cobbles are not much in evidence but there is a suggestion of morainic topography there indicated. The rock fragments become more numerous in passing southward, being noticeable between Wayne and Eloise and abundant in the northern part of Romulus township, but obscured by sand in the SW. 1/4. Southward across the western strip of Huron township, the belt may be followed, leaving at the SW. corner and entering Monroe County, crossing Exeter township near Scofield, Maybee, between Raisinville and Grape to Federman, where it disappears again under a heavy deposit of sand. The general course leads one to expect the reappearance of the belt just north of Ottawa Lake and here again it is seen, passing into Lenawee County and entering Ohio from three to four miles west of the SE. corner.

Across Wayne County, this boulder belt drops from 680 feet above sea level to about 620, entering Monroe County between the contours of 620 to 630 feet. South of Maybee the belt turns upon higher ground instead of following the contours, or dropping to

lower level.[8] A similar and parallel boulder belt, the Grosse Isle, lying in the eastern part of the county, shows the same anomalous behavior at the same latitude, suggesting that, at both stages of ice halt, an extra pressure to the westward was being exerted from the direction of the Erie basin.

Protected somewhat by the Detroit moraine, this pressure from the east would become greater opposite the axis of the Erie basin and might be expected to cause such westerly deflection of the ice margin. Entering Ohio, both boulder belts swing around parallel with the contours but have not been followed for any considerable distance. If they do really indicate an ice margin, during a temporary stage of halt they will be found looping around the Maumee valley inside of the Defiance moraine. In the opposite direction, from the NE. corner of Livonia township, there rises a flat, wave-washed ridge which may be a continuation of the Scofield boulder belt, although not absolutely connected with it. It has a breadth of one to two miles, rises rather rapidly from 640 feet to 780 at Birmingham, deflecting the North Branch of River Rouge to the southwestward and passing without break into the Birmingham moraine.[9] According to one interpretation this strip of moraine, and the boulder belt which appears to be its continuation, were formed by the ice margin of the Erie lobe; while the correlative moraine, that from Birmingham to the northeastward, was formed simultaneously by the Huron lobe. During and previously the Detroit moraine was in process of formation beneath the ice along the line of junction of the two lobes, extending backward into the ice and inclined at a rather high angle to the ice margin.

From the neighborhood of Birmingham, there swings into Wayne County across the NE. corner of Redford and NW. corner of Greenfield townships a broad swell in the till to be known as the

8. This anomalous behavior for a boulder belt which marks an ice margin has led Mr. Taylor to question this interpretation of the writer and to suggest, as an alternative hypothesis, that these boulders may have been concentrated in drainage channels upon the surface of the ice. Although the Labradorean ice sheets probably carried few boulders upon their surfaces, in their waning stages, the englacial boulders must have been concentrated upon the surface by melting and may be assumed to have worked their way into neighboring ice channels. However, it is difficult to believe that such channels could have had a breath of two to three miles, that their streams could have flowed for many miles so nearly parallel with the theoretical margin of the ice lobe and that three so nearly parallel great channels could have existed upon the same lobe as are necessary to account for the Rawsonville, Scofield and Grosse Isle boulder belts (see pl. X). In view of these difficulties, of the relation of these belts to the recognized moraines, that they seem to mark what must have been the approximate ice border at certain stages of retreat and that a halt or two of the ice margin was to have been expected between the Defiance and Grosse Isle positions, the writer has been induced to accept the view that these boulders were dropped at the margin of the ice during a stage of halt or during a relatively sluggish condition of the ice front.

9. This moraine was located on the Nellist map, published in the 1907 Annual Report of the Michigan Geological Survey. It will be named and described in the monograph of the U. S. Geological Survey, "The Pleistocene of Indiana and Michigan," by Messrs. Leverett and Taylor.

Detroit moraine.[10] As a physiographic feature it is very inconspicuous, being unrecognizable when one stands upon it, and still it controls the drainage and is indicated by the contours and beach ridges (see Pl. X). As it enters the county, it is some seven miles broad, having an elevation of 660 to 670 feet and carrying surface swamps in sections 4 and 5 of Greenfield which are drained to the north, southeast and southwest. Passing southeastward across Greenfield township, it crosses the city of Detroit, dropping more or less gradually and narrowing to a point about one mile east of the City Hall upon Champlain Street. In Highland Park, the elevation of the crest is 640 + feet, about 595 at the City Hall, then descending rather rapidly to the river. It is believed by Taylor and Leverett to have been formed *subglacially,* between the Huron and Erie ice lobes, the former lying on the northeastern, the latter upon the southwestern side, and thus to represent a *subglacial-interlobate* moraine. This theory of its formation accounts very satisfactorily for its broad, smoothed and poorly defined character, squeezed in between the two lobes and being constantly overridden by the marginal portions. The moraine was followed by the writer across Essex County, southeastward towards Leamington and a study was also made of the various railway profiles available. Throughout this portion of its course, it possesses the same general characters seen in Wayne County, both strips being characterized by the absence of boulders, except upon the western slope, north of Ruthven, where they seem to have been concentrated by wave action. In the city of Windsor, the elevation ranges from 600 to 620 over the higher portion of the moraine, the slope dropping to 608 feet eastward along the line of the Canadian Pacific Railway, in a distance of three miles. The branch of the Michigan Central from Amherstburg, northeastward across Essex County, gives a good section of the moraine although it is cut obliquely and its breadth thus increased. From the north-south township line between Anderdon and Colchester North townships to the middle of Rochester, a distance of 16 miles, the profile of the

10. This name was first used by Taylor in 1897 (Bulletin Geological Society of America, vol. VIII, p. 39), for the Mt. Clemens moraine and that portion of the present Detroit moraine lying in Essex County, Ontario. It was further described and figured in 1899 (American Geologist, vol. XXIV, p. 18 and pl. II) as marking an ice front and was correlated with the Euclid moraine of Leverett in northern Ohio. In his Monograph XLI, of the U. S. Geological Survey, published in 1901, Leverett figures this moraine as marking the position of the ice front during the second stage of Lake Maumee and assigns it a "probably subaqueous or subglacial" origin (plates II and XXI). Fig. 5 of the Ann Arbor Folio (U. S. Geological Survey, No. 155. 1908) indicates the same course for this moraine. More recent studies of these two investigators, however, have led to the extension of the Detroit moraine northwestward to Birmingham, as described in this report, the separation from it of the Mt. Clemens moraine, and the belief that it was formed *subglacially* between the Erie and Huron ice lobes.

railway shows a very regular swell rising from 608 to about 646 feet, above sea level, and dropping again to the former level, thus giving a relief of 38 feet and an average slope upon either side of the crest of about 5 feet to the mile. Parallel with the Lake Erie shore, the profile of the Lake Erie and Detroit River Railway, furnishes another slightly oblique section of the moraine, with a breadth of eight miles and a relief of 126 feet, with the much more pronounced average slope of 32 feet to the mile. The profile of the branch of the Michigan Central from Windsor to Essex and the proposed line of the Windsor, Essex and Lake Shore Rapid Railway, both of which follow the crest of the moraine for several miles, show an even contour gradually rising toward the southeastward to an elevation of 735 to 740 feet. This moraine at present writing is being made the subject of study by Taylor from whom we shall learn its exact course. It is now believed by him to turn eastward just north of Leamington, passing through Wigle into Romney township.

Within the limits of Wayne County this moraine is strewn with beach and dune sand and carries very few boulders. The thickness of the drift composing it is 80 to 90 feet, where it enters from Oakland County, increases to 120 to 130 feet in the western part of the city and 130 to 150 feet in the eastern part. "Hard-pan", by which term the drillers refer to a very compact, stony till, was encountered in a number of wells sunk into this moraine, but these records were not sufficiently numerous to suggest a core of pre-Wisconsin till. In Detroit and Windsor, there seems to be conclusive evidence that the Detroit moraine was overridden by the ice as it was gradually being uncovered from the northwest to the southeastward, permitting the formation across it of a younger frontal moraine and repeating again what seems to have occurred at Birmingham.

Taylor recognizes in his studies of the region a moraine, which he designates as the Mt. Clemens and regards as of the frontal water-lain type, passing directly northward from Detroit, through Hamtramck township into Macomb County. So far as Wayne is concerned, it is poorly defined and practically unrecognizable, except for a sprinkling of boulders and cobbles in the township which might have been referred to the Detroit moraine. It must have been formed by the Huron ice lobe, just previous to the formation of the Emmet and if there was a correlative of the Erie lobe, it must have been overridden by the ice and destroyed by a temporary advance to the position of the Gross Isle moraine.

The youngest moraine within the limits of Wayne County skirts the eastern margin, following the course of Detroit River and consisting of a number of approximately parallel and remarkably regular till ridges, or gentle undulations. The belt of country thus involved is strewn, more or less abundantly, with boulders, cobbles and coarse pebbles, which in the bed of Lake Rouge have been completely obscured by deposits of sand. These ridges and undulations lie mainly between the contours of 580 and 600 feet and hence are not well indicated upon the topographic sheets (see Pl. X). The level of 600 feet and over is attained in the SW. corner section 4, Monguagon township, in the SE. portion of Grosse Point and also in Detroit, Windsor and Sandwich. The general course of the moraine is from 35° to 40° east of north and shows a maximum breadth of eight to nine miles in the vicinity of Trenton and Amberstburg. Westward and southwestward from Trenton, the parallel ridges are especially well defined.[11] The profile of a proposed railway line from Ypsilanti to Trenton (Detroit office of the Michigan Central Ry.) shows a series of thirteen crests in the two miles west of Trenton, the vertical distance from crests to troughs of the largest amounting to 12 to 13 feet. The drainage of Taylor, southwestern Ecorse and Monguagon townships is deflected to the southward by the SE. ridges. Upon Grosse Isle, Sugar Island and Hickory Island, in Detroit River, similar ridges are much in evidence following the general direction of the moraine, rising to a height of approximately 600 feet. A strip in Detroit River for 2½ miles alongside of Stony Island is shown by the river chart to have boulders in the bed which have been a serious menace to navigation at the "Lime Kiln Crossing." During the construction of the Livingstone Channel at this place, some 150 to 200 acres of the river bed have been laid bare by means of a cofferdam and a belt of boulders thus brought to view (see Pl. XI, A). East of Amherstburg, for a distance of four to five miles in Anderdon township, similar morainic swells may be observed gradually dying out eastward and northeastward. In the village of Amherstburg itself, the ground has an elevation of about 595 feet above sea level, or some 21 to 22 feet above the river level, rising slowly northward and eastward to 605 to 608 feet.

The western margin of the moraine crosses the river just south of Wyandotte and reappears again at Detroit. Northward from Amherstburg, upon the Canadian side, the boulders are quite abundant for a distane of two to three miles from the river, until

11. The portion of this moraine from Wyandotte to Brest was mapped in 1902 (Journal of Geology, vol. X, p. 195), as far as it had been traced at that time.

obscured by the Lake Rouge sands. East of Sandwich and south and southeast of Windsor, the ridges and boulders are again in evidence. In Windsor, four distinct ridges are to be seen, the crests of which range from 598 to 602 feet, and a broad swell two miles in width, reaching an altitude of 620 feet, is *superposed on the crest of the Detroit moraine.* In Detroit, these gentle morainic ridges are very noticeable as one looks along the streets running back from the river, giving them a fluted, corrugated appearance. The profile of the Michigan Central Railway shows a ridge on Howard Street 550 feet broad, with a depression 300 feet across, and then a gradual rise from Baker to 20th Street, where the elevation is 600 feet, with a gradual drop beyond. Some 15 to 16, more or less well defined crests, may be counted within a distance of two miles. Upon the eastern slope of the Detroit moraine, a very regular series of these till flutings is seen just northwest of Elmwood Cemetery, between Hunt and Willis streets, where seven may be counted, spaced almost exactly two blocks apart and dying out to the east and west. Similar low ridges are seen at the Detroit Water Works, in the eastern part of the city and upon Belle Isle. The bed of Detroit River opposite the city shows a series of ridges, having the same general trend as those upon the land and the islands themselves in the river are found in the two localities where crossed by this moraine (see Pl. X). Along the Lake St. Clair shore, Grossepoint township, a conspicuous ridge is seen just NE. of Windmill Point, forming there a bluff 12 to 14 feet high (Emmet moraine). Indeed, it seems probable that the *grosse pointe* here developed owes its existence to the presence of this moraine, which has thus enabled the land to better resist the encroachments of the lake. Just north of Milk River Point the *L'Anse Creuse* results from the destruction of the morainic ridge, the waves opposite the broader portion of the lake having gotten in their work behind the moraine (see Pl. XI, B). The chart of Lake St. Clair shows that a clay ridge, stony in a few places, extends slightly east of north, for some three or four miles across the western margin of the lake, the remnants of this destroyed moraine. The point of land just east of Mt. Clemens, although delta-like upon the map, is *reported* to be *till* and seems to owe its existence also to this morainic ridge. From the general trend of the moraine it appears probable that the narrow ridge shown on the Nellist map, running northeastward from near Anchorville toward Port Huron, is the continuation of this moraine, beyond which it is closely associated with the Port Huron moraine.

From Trenton southward, the ridges become faint as Huron River is approached and in places boulders are abundant. South of the Huron, the ridging is very indistinct but the former ice margin is still indicated, the writer believes, by a boulder belt which passes east of Newport, near Brest, north and west of Monroe and southwestward across Monroe County. It is obscured in places by the sands of the Elkton, Grassmere and Wayne beaches, but appears in force east and south of Ottawa Lake and has been followed into Ohio four miles, as far as Glantown. From the Huron, the topographic contours are followed by the boulder belt, until it comes opposite the Erie basin, as in the case of the next older belt, the Scofield, when it mounts the contours from 580 to 680 in a distance of 25 miles, or at the average rate of 4 feet to the mile. Entering Ohio, the belt swings around again parallel with the contours and has not yet been followed through the Maumee valley. The name Grosse Isle is suggested for this boulder belt and for the moraine, of which it seems to be a continuation, both having been deposited in deep water. From the present site of the Huron southward, the ice margin was sluggish; northward to Detroit it exhibited a very regular, rhythmic series of advances and retreats, pushing up the till into regular and often very evenly spaced ridges parallel with the front. Theoretically the Gross Isle moraine extends to Detroit only and was formed by the Erie ice. Its direct extension northward along the western margin of Lake St. Clair was formed by the Huron lobe and is named by Taylor the Emmet moraine in the forthcoming monograph. Both were formed simultaneously and extend to the crest of the Detroit moraine with no recognizable line of demarcation, indicating a perfect blending of the Erie and Huron lobes so far as the ice margin was concerned.

The hypothesis that the Detroit moraine is of the nature of a subglacial interlobate receives much support from the field evidence; its general direction, poorly defined character and breadth being out of harmony with the other moraines of the region. It has the appearance of having been overridden by the ice, its ridges smoothed out and swept clean of boulders, which would almost certainly have been deposited while an ordinary frontal moraine of such magnitude was being formed. In Oakland County, Leverett found evidence in the distribution of the flowing wells that the beds of gravel included in the moraine slope in *opposite* directions from the crest, suggesting that it might have been formed as the

joint work of the ice lobes upon either side of the morainic ridge.[12] Moraines of this type have been observed by the writer in the Canadian Rockies and described by Wilcox as the joint work of a trunk glacier and its tributary.[13] An alternate hypothesis, however, would be that the Detroit was a *frontal moraine* of Early Wisconsin age, that it was overridden by the Late Wisconsin ice advance without being completely destroyed and that the frontal moraines formed during the retreat of the latter were deposited directly across its back without break in their continuity. Upon the former hypothesis we expect, but do not find, any indication of a *notch* just where the two great lobes united along the crest of the moraine. The moraines to the north and south of the Detroit moraine seem perfectly continuous and give no line of separation such as we may often observe in modern glaciers of much smaller size. A detailed study of the glacial striae of southeastern Michigan and western Ontario shows that just previous to the last northwesterly advance of the ice, there was a general and more powerful movement south-southwest,[14] the direction needed to have formed the Detroit moraine, if of the type now assumed and to bring it into harmony with the Early Wisconsin moraines of southwestern Ohio and eastern Indiana.[15] Still another line of evidence that seems to favor this alternative hypothesis is the direction of the striae at the Amherstburg quarries (Anderdon). In order to have formed such a massive, sub-glacial interlobate moraine as the Detroit it is fair to suppose that there must have existed a general movement of the ice from the axis of each lobe toward this common margin beneath which the morainic matter was accumulating. Since the Anderdon quarries are only some 9 to 10 miles from the crest of the moraine we might expect some indication of a northeasterly movement of the bottom ice to have been recorded upon the embossment of limestone at this locality. Instead, however, the striae indicate, as at Trenton, a late northwesterly movement of the ice, which was preceded by a more vigorous one in the direction of south-southwest. The evidence from the striae is thus more favorable to the alternative hypothesis of the Early Wisconsin age of the Detroit moraine, while at the same time it satisfactorily explains its greatly subdued character, the general absence of bould-

12. Flowing Wells and Municipal Water Supplies in the Southern Portion of the Southern Peninsula of Michigan, 1906, p. 190. Water-supply and Irrigation Paper No. 182, U. S. Geological Survey.

13. A certain Type of Lake Formation in the Canadian Rocky Mountains: Journal of Geology, vol. VII, 1899, p. 255.

14. Sherzer, Ice Work in Southeastern Michigan: Journal of Geology, vol. X, 1902, pp. 207 and 215.

15. Leverett, Glacial Formations and Drainage Features of the Erie and Ohio Basins: Monograph XLI, U. S. Geological Survey, 1902, p. 304.

ers and the fact that it carries upon its back, at least, two continuous moraines of younger age.

Till plains. Crossing the extreme northwestern corner of the county, in a northeast-southwest direction, lying between the Ft. Wayne and Northville moraines, there occurs an elevated till plain, having a general elevation of 970 to 980 feet above sea level. A low crest serves as a divide to deflect the surface drainage to the north or south. In sec. 6, Northville, the plain is largely strewn with sand and gravel, the remainder being clay.

From the Defiance moraine eastward to the Grosse Isle moraine above described, there was formed a very broad till plain, remarkably even and regular were it not for the beaches, dunes, deltas and subsequent stream erosion. The general direction of the surface slope is southeastward in the direction of ice retreat, and averages six to eight feet to the mile. This is too slight to be detectable by the eye but is enough to control the surface drainage strongly, except where barriers have been interposed. This deposit is the ground-moraine, formed between the bedrock and the ice sheet, with its surface subdued and smoothed by the last ice advance. After leaving the Defiance moraine, during the first two stages of halt described, there was practically no disturbance of the till plain while the boulder belts were forming. This till deposit is thinnest in the southeastern portion of the county, Brownstown and Monguagon townships, where in a few places the rock is actually bare, but thickens in all directions. Over most of the county, it ranges from 40 to 100 feet in thickness. In the northwestern portion of Canton township, a depression in the rock surface gives a thickness of 140 feet and, in the northeastern corner of Van Buren, 180 feet. In Hamtramck and Grosse Point townships, deposits 170 to 180 feet thick are noted in the well records.

Although the great body of this deposit is a bluish till, rather sparingly charged with pebbles, there are irregular seams and lenticular masses of sand and gravel embedded in it and the problem of getting water for farm use consists in locating these. Although thus of great economic value in furnishing a pure and abundant water supply these "quicksand" deposits are a menace to the stability of tall buildings in the cities. Their occurrence can not be predicted and only a series of borings can be relied upon to prove their absence. In securing a safe foundation for the Penobscot Building, in Detroit, this quicksand embedded in the till entailed an extra expense of $20,000.

The most complete examination of the structure of this glacial deposit ever attempted in this region was in connection with the Michigan Central tunnel across Detroit River. This, upon the Detroit side, (east bound track) started with an open cut of 1540.07 feet; an approach tunnel 2128.89 feet; subaqueous tunnel trench 2622.56 feet; Windsor approach tunnel 3192.14 feet and an easterly open cut of 3300 feet. This gives a continuous section of 12783.66 feet, or 2.42 miles, through the till and to a depth of nearly 500 feet above sea level, or about 72 feet below the level of the river. A very extensive preliminary set of borings was made as a basis for estimates of cost of construction and these with their records are shown in Pl. XII. An examination of these boring records, which in the river portion were continued to bedrock, shows that the great bulk of this rock cover consists of glacial clay, with irregular and disconnected masses of sand and gravel. The clay was classified as *hard* and *soft*, but genuine hard-pan was not encountered and boulders and pebbles were rather scarce. Much of the clay was sliced out with U-shaped knives, operated by two men, the long strips cut into short sections with the spade and handled in the hands. The cross-section of the tunnel was made more nearly circular than at first planned in order to better withstand the pressure from the soft clay. It was this tendency of the clay to "creep" or flow that caused the failure of the Michigan Rock Salt Company to reach the rock near Ecorse in 1902. A hollow brick cylinder, 12 inches thick and 15 feet in diameter, was constructed at the top and allowed to settle as the excavation proceeded. At a depth of 55 feet the clay was forced in at the bottom almost as rapidly as it could be removed and it was found necessary to increase the thickness of the brick casing to 30 inches. At a depth of about 75 feet, when within six feet of bedrock it was found impracticable to proceed and the project of mining the rock salt was temporarily abandoned. This condition of the deeper till deposits leads to the inference that we have in the Detroit region only the Wisconsin till.

The iron constituent of the till-sheet has been very generally oxidized to a brown, or yellow, and to a depth of a number of feet, testifying to a considerable period of exposure since the withdrawal of the ice. In a few places, the blue clay comes very close to the surface but generally is overlain by from 5 to 15 feet of the yellow or brown variety. In the very complete tunnel series of borings of the 155 observations made the average thickness of this layer is 10.45 feet, the maximum thickness noted being 25 feet upon

the Canadian side, near the river. Beneath the river, this discoloration of the till is slight in amount, or absent, due very probably to the scarcity of oxygen necessary for the alteration of the iron. When the vertical surface of a bed of till is exposed the material dries, contracts more or less and a system of fine vertical joints makes its appearance. At a number of localities a bright blue discoloration of brownish till was observed along the surfaces of these joint-planes, penetrating the clay to a depth of a tenth of an inch. The effect appears to be due to water making its way along these fine seams, carrying some ingredient (possibly carbon dioxide gas) which has a tendency to restore the original color of the till. Owing to its ordinary very compact nature, however, and fine texture, this type of clay is quite impervious to water, allowing only relatively small quantities to enter and for only a slight distance. The more soluble ingredients of the soil, such as calcium and magnesium carbonate, are slowly dissolved and removed from the surface portion and the depth and completeness of this leaching effect are regarded as an indication of the length of time that the till surface has been exposed. Various factors, however, must be considered in all such estimates; such as, the amount of precipitation, the surface slope, the nature of the subsoil, the covering of sand or water, the amount of carbonate originally present, etc. The simple test for these carbonates that may be applied is to place a few drops of dilute hydrochloric acid[16] upon a lump of the clay to be tested and noting the amount of effervescence that takes place. When so tested, the Wayne County till deposits will be found to have been more or less perfectly leached to a depth of 6 to 18 inches, just below which depth the effervescence is often more vigorous than at the greater depths. This result is probably due to the concentration of the carbonates removed above through redeposition from the solutions which have difficulty in escaping from the deeper layers of soil. A similar concentration of iron oxide may often be observed between the soil and subsoil layers.

Glacial outwash. When the precipitation over the ice sheet occurred as rain and when the superficial ice or snow was rapidly melting, especially during the waning stages, quantities of water collected in the surface channels on the ice forming powerful torrents. These eroded and melted their way into the ice, forming channels (see Pl. XIII, A.), the water of which uniting into systems, was able to work more deeply into the body of the ice, and to seize and transport whatever debris came within its reach or

16. This is made by taking four parts of water and one part of the commercial acid.

was delivered to it. Sand, pebbles and boulders even, were often thus hurried along to the margin of the ice. When crevasses, or moulins, were encountered, the surface streams found their way to the inside, or bottom of the ice mass and englacial, or subglacial tunnels were formed (see Pl. XIII, B.) through which often coursed mighty torrents, charged with all kinds of rock debris. In some cases, the discharge from the lobe was of a more general character and might extend for a considerable distance along the ice front. Issuing from the ice under more or less pressure, the velocity of the water would be checked, the coarsest material dropped first, the finer next and the finest sediment retained until a quiet body of water was reached. Small marginal lakes were often formed where the topography permitted, sometimes the turbid streams coursed along the margin of the ice, gaining in volume until an opportunity for escape was afforded when they left the ice to follow the general course of drainage for that region.

The sand and gravel deposited along these valleys often extended for several miles, forming so-called "valley trains", the finer sediment reaching the quiet bodies of water and giving rise to deltas and lake deposits. Under exceptional circumstances, the subglacial tunnels became clogged and more or less filled with irregularly stratified sand and gravel, from which the ice melted without destroying the deposits, forming ridges known as eskers. Broad expanses of sand and gravel, spread by the escaping waters in front of the ice, gave rise to "outwash aprons". Owing to the original angular condition of the sand grains and pebbles and the relatively slight opportunity for erosive action before deposition takes place, the materials of which these deposits are composed are generally imperfectly rounded and may show signs of glaciation.

The glacial outwash partially covering the till plain in sec. 6, Northville township and the kame formations associated with the "middle moraine" have already been noted in the preceding chapter. Between this moraine and the Defiance, there is an old drainage channel (see Pl. XIV) floored with sand and gravel, about a mile broad which carried the drainage, during the Defiance halt, southwestward across Salem and Superior townships, in Washtenaw County, to the Saline River. This channel involves mainly sections 3, 4, 7, 8, 9, 17 and 18 of Northville and 19 of Plymouth townships. The bed now has an elevation of 830 to 865 feet above sea level, rising to 880 feet, is more or less swampy and the direction of drainage has been reversed, now flowing northeastward into

the Middle Rouge. In places the banks rise to a height of 100 feet above the floor of the channel. Where crossed by the Pere Marquette Railway (SW. corner of Northville and the NW. Corner of Plymouth townships) the channel has a breadth of 5,200 feet, the lowest level of the valley floor 834 feet, the crest of the eastern bank 852 feet and that of the western bank 891 feet. During all the subsequent stages of halt, within the county limits, the ice front stood immersed in the waters of some one of the glacial lakes, giving no opportunity for the formation of definite recognizable deposits by direct glacial drainage.

Beaches and associated dunes. The entire series of glacial lake beaches, or their correlatives, mentioned in the preceding chapter is found within the limits of Wayne County, beginning upon the eastern slope of the Defiance moraine and reaching down to the very edge of Detroit River. The upper members of the series contain considerably more gravel and are practically free from dunes, the lower members consist mainly of sand and are often disguised by dune deposits and confused by sand bars, making their tracing often difficult and uncertain.

The three Maumee beaches enter the county from Washtenaw in sec. 7, Canton township, and pass northeastward across Plymouth, Northville and Livonia townships. The uppermost of the three is moderately well defined and consists of a low gravel ridge resting upon the steep slope of the moraine which served as a barrier to the waters of the lake. Just west of Plymouth (SW. 1/4 sec. 22), the profile of the Pere Marquette Railway shows that it is about 200 feet broad and that it rises about 4 feet above the general slope of the moraine. In places it is represented by a wave cut shelf at a somewhat lower level than the beach itself. It is interrupted frequently, is often obscure and difficult to follow with any degree of certainty, owing, apparently, to the relatively short time that the waves were operative in this region, or to their weak action. It has had only a slight effect upon the drainage, the short rapid streams down the eastern slope of the moraine being able to break through without undergoing much deflection. The crest of the beach in this section is about 810 to 812 feet above sea level. The second, or middle of the three Maumee beaches, pursues a more direct course, from a quarter to an eighth of a mile east of the upper, its distance depending upon the rapidity of slope of the moraine. Its general elevation is given by Leverett for the Ann Arbor quadrangle, which extends into Wayne County, as 20 feet below the upper beach, making its elevation about 790 feet

above tide. The Lower Maumee has the appearance of having been submerged and this is interpreted as meaning that it was formed before the Middle and that a readvance of the ice cut off the temporarily lower outlets and raised the level to that of the Middle beach. This subjected the lowest beach to more or less wave action, during the period of rise and subsequent fall of the waters and gave opportunity for depositional covering during the life of the second stage of the lake. The interval between the Middle and Lower beaches is about the same as that between the Middle and Upper, namely about 20 feet, making the approximate elevation of the Lower beach in Wayne County about 770 feet above tide. Just west of Plymouth (SE. 1/4 sec. 22 and NE. 1/4 sec. 27), there is a pretty well defined section of this beach, but it can be followed only with difficulty throughout its course (see Pl. X).

If all the beaches were as well defined as the Whittlesey, there would be no trouble whatever in mapping them and thus determining with certainty the form and size of each of the various glacial lakes. It was first described in this section by Hubbard in 1840[17] as consisting of a gravel ridge, several hundred feet broad, with an average height of 12 to 15 feet above the level lands upon either side and as plainly representing a former beach line. Before the country had been drained, the advantage of this elevated gravel ridge as a roadway was appreciated and some of the highways along its crest are still retained in Canton, Plymouth and Northville townships. The elevation assigned to the beach at that time was about 680 feet above sea level (107 to 108 feet above the level of Lake Erie), but our more accurate topographic survey gives it an elevation of 736 to 740 feet. Several railway profiles give the beach a breadth of 300 to 900 feet and a height above the general surface of the country of 7 to 8 feet, sloping more rapidly upon the westward, or landward side, and more gently toward the former lake. Owing to its elevation, drainage, soil and ease with which water may be procured from it, the ridge is very generally utilized as the sites for homes, barns (see Pl. XV, A.), schools, churches and cemeteries. Well records indicate a thickness of the gravel layers of 10 to even 25 feet. A splendid section of what is in part beach and in part delta is seen just east of Plymouth (see Pl. XV, B and Pl. XVI, A.) where the Pere Marquette Railway has been utilizing the gravel (SW. 1/4 sec. 24). At the time of its examination in 1902, there was shown one foot of yellow, gravelly

17. Third Annual Report of the State Geologist, House Document No. 8, pp. 102 to 108.

loam; 15 inches of fine, stratified gravel dipping westward; 15 inches of horizontally stratified sand; and about 20 feet of cross-bedded sand and gravel, embedded in which at one place were the remains of a log as reported by the workmen. At one other locality a similar find was reported in a well dug upon the beach.

The beach enters the county from Washtenaw in the SW. ¼ sec. 19, Canton township and pursues a very direct northeast course across the northwestern corner of the township and southeastern corner of Plymouth. About a mile northeast of Plymouth, it was deflected a half mile to the eastward in crossing the old delta of the Middle Rouge, thus introducing a slight curve into its otherwise direct course. The ridge crosses the northwestern corner of Livonia township and leaves the county from the NE. ¼ sec. 5, passing into Oakland.[18] Throughout this section the beach is everywhere a built ridge and indicates rather long continued and vigorous wave action.

In secs. 7 and 8 of Livonia the cobbles have been concentrated in front of the beach, in places so thickly as to almost form a boulder pavement. Without a knowledge of the possible function of ice dams as great restraining walls, Hubbard in his early report (*loc. cit.* p. 106), speculated upon the great extent of territory covered by this lake and the possible source of the water, suggesting a depression and marine invasion. Finding evidence that, at least, a portion of the water was fresh, he considered the possibility of the Appalachians serving as the barrier across the Mohawk and St. Lawrence basins, thus deflecting the drainage to the Mississippi.

"That the lakes once discharged their waters in this direction, such additional evidence is furnished by the appearance of the country, that in this our argument but serves to add confirmation to the general opinion."

For reasons previously assigned the Arkona beaches are very generally poorly defined and at times difficult to recognize. Sometimes they consist of broad, low built sand ridges scarcely over a foot high; sometimes the sand appears to have been swept away and there remains only a narrow belt of pebbles resting upon the clay to mark its position. In places lake sediments have been introduced, thereby obscuring the beach materials. Where sand and gravel were abundant, opposite the mouths of the rivers, stronger ridges were formed and these better withstood the action of the

18. Upon the Higgins' map of Wayne County published in 1840 with the third annual report of the state geologist, the beach is correctly located until the town line between Northville and Livonia is reached when it turns suddenly to the north and follows this town line.

waves. Within the limits of Wayne and Washtenaw counties two, and in places three beaches, may be recognized, a mile or more apart, depending upon the rapidity of the surface slope. Farther north Taylor has indentified four distinct ridges of Arkona age. The two lower enter the county from Washtenaw in the southwestern corner of Van Buren township (sec. 31), being deflected eastward by the old Huron delta. The highest ridge enters sec. 18, just north of Rawsonville, and with the other two, turns northward through western Van Buren and Canton townships, swinging to the northeastward and continuing roughly parallel with the Whittlesey beach across Canton, Plymouth and Livonia townships. As in the case of the previously formed beaches, in crossing the delta of the old Middle Rouge, the ridges become better defined and are displaced to the eastward. They leave the county in NE. ¼ sec. 4 and NW. ¼ sec. 3, Livonia, the upper ridge showing the best development during the last mile and containing considerable gravel.

At Denton, the ridges are rather close together and contain considerable sand, ranging in elevation from 693 to about 707 above sea level, furnishing the site for the village cemetery. In the NW. ¼ sec. 1, Canton, there occurs a gravel ridge 900 feet across and 4 to 5 feet above the general level, having an elevation of 696 feet, apparently the lowest beach. East of Plymouth the profile of the Pere Marquette Railway gives a section of Arkona beaches that were built upon the Rouge delta. A very broad crest carrying several minor ones, some 2,600 feet across and about 5 feet above the general level, passes from the SW. ¼ sec. 24, Plymouth, into sec. 25. According to the railroad elevations, the altitude is 713 feet above sea level. Some 4,000 feet eastward, near the town line between Plymouth and Livonia, another 700-foot crest occurs on a broad swell which is 2,000 feet across and rises 6 to 8 feet above the general level. Upon the eastern slope, in sec. 30, Livonia, ridges are shown at 695, 689 and 683, the latter probably representing the Warren beach. The presence of these well defined ridges of Arkona age, resting upon the old deltas of the Huron and Middle Rouge, seems to prove that these deltas were formed during the Arkona stage of the glacial lakes, rather than during the Whittlesey stage, since if of latter age, the beaches would have been buried in the delta deposits. The conclusion seems justified also that the rise and fall of the waters over these ridges must have been rather rapid, otherwise the waves would have leveled them more completely.

A. KAME UTILIZED AS DWELLING SITE AND GRAVEL SUPPLY.

B. SECTION OF KAME AT NORTHVILLE. OWNED BY D. U. RY.

A. BOULDERS OF GROSSE ISLE MORAINE CONCENTRATED UPON DETROIT RIVER BED AND EXPOSED DURING THE CONSTRUCTION OF THE LIVINGSTONE CHANNEL.

B. MILK RIVER POINT, LAKE ST. CLAIR. BOULDERS OF MORAINE CONCENTRATED BY WAVE ACTION AND FURNISHING A NATURAL PROTECTION FOR THE BANK.

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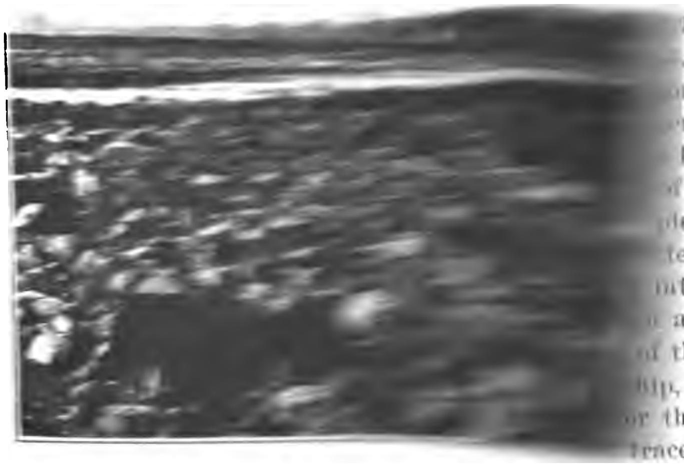

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township, Monroe County,
Sumpter township), and
enter of the township. Sand

After pursuing a rather tortuous course in Augusta township, Washtenaw County, the Warren (Forest) beach enters Wayne County in sec. 7, Sumpter township, as a somewhat faint sand and gravel ridge. The broad delta of the old Huron has deflected the ridge eastward by some seven miles. It passes northward through Van Buren, intercepted by the Huron and showing very indistinctly for the next couple of miles. From sec. 10, it assumes definiteness and becomes more gravelly northward, furnishing a small gravel-pit in SE. 1/4 SW 1/4 sec. 34, of Canton township. Following due north, the beach shows as a rather distinct low ridge at the village of Canton, furnishing the site for the church and continuing just east of the central meridian of the township, to about the middle, where it disappears for a couple of miles. In the northern portions of secs. 11 and 12, separated sand strips seem to mark the location of the beach, curving into sec. 1. The elevation of the crest throughout is about 682 feet above sea level, the beach following closely the 680 foot contour of the topographic map. This contour enters sec. 6, Nankin township, and, although the slope to the eastward is unusually rapid for this region, falling 24 feet in a half mile, there is but slight trace of the beach. Just north, however, in sec. 31, Livonia, it takes form as a low sand crest, passes through the village of Nankin, following the road north and near the middle of the township breaking up into separate ridges or bars. In secs. 9 and 10, it is well developed again and leaves the county in the NE. 1/4 sec. 3. What appears to be a very well defined bar, having an elevation of 660 to 665 feet, appears in sec. 33, striking a little east of north through secs. 28 and 21, breaking up in sec. 15, but still showing traces in 10 and 3. Most of this region was marked upon the Higgins' map as "oak plains" and "oak openings", owing to the sparse timber growth.

The Wayne beach, the next in the series as we move eastward, is the most sandy of any thus far described and located, being throughout its course quite similar to the northern portion of the Warren beach. The real shore line is often disguised by dunes and bars making it difficult to locate the beach and to decide upon its approximate height. Most of the sand associated with the Wayne shore line lies between 650 and 660 feet elevation and the average height of the beach crests may be taken as about 654 or 655 feet. It enters Wayne County from London township, Monroe County, at the extreme SW. corner (sec. 31, Sumpter township), and passes northeastward across the center of the township. Sand

was distributed to the westward for a mile or two, suggesting that the prevailing winds, or perhaps only the strongest winds, were from the east, instead of from the west as at present. The water in front of the beach was shallow and numerous bars were formed by wave action. In the SW. part of Romulus township, there is an unusually heavy development of sand, striking northward through the village of Romulus; north-northeastward through the western half of the township; across Nankin township, through the village of Wayne, and just west of the central meridian. The profile of the electric railway at Wayne shows a very broad, flat crest, 3,400 feet across and 5 feet above the general level, reaching an elevation of about 655. In Livonia township, the Wayne beach is not well defined, being represented by disconnected scraps of sand ridges. This is apparently due to the fact that the Detroit moraine formed a broad, rounded peninsula, projecting southward into Wayne County to a distance of three to four miles, giving rise to an embayment in northeastern Livonia and northwestern Redford and thus protecting the region from wave action. Upon the lakeward side of this peninsula and about its southern extremity, a well defined succession of sand ridges occur in the north central portion of Greenfield township. Just west of Palmer Park, the ridges become much complicated and in the park seem to mingle with dune ridges of the Grassmere stage (see Pl. X). Taylor has recently found evidence that this beach was submerged for a time just as in the case of the Arkona and Lower Maumee, an advance of the ice closing up the outlet of Lake Wayne and forcing the water to a higher level.

In its general characteristics and mode of development, the Grassmere (Lundy) beach is very similar to the Wayne just described and, through the bars of the latter and dunes of the former, the two are often very intimately associated, as in Greenfield, Romulus and Sumpter townships. The approximate elevation may be given as 635 feet above tide, but ridges, apparently the result of easterly wind action, rise 12 to 18 feet higher. It enters Sumpter township from Exeter township, Monroe County, with a complicated set of disconnected sand ridges amongst which it is difficult to pick out any particular beach ridge. Cutting across southeastern Sumpter and northwestern Huron townships, the system of sand ridges passes New Boston into Romulus where they become more crowded and prominent, especially in secs. 33, 28 and 21 and have a NW.-SE. trend. At the village of Romulus, the beach and the ridges swing around to the northeastward and then

northward, cutting through Nankin township just east of the central meridian, showing some strong ridges in secs. 1 and 2. In Livonia, a long, well defined ridge assumes shape in the NE. ¼ sec. 27, branching in the SE. ¼ sec. 22, one branch passing northward for a mile, the other curving abruptly eastward for two miles through the lower half of secs. 23 and 24. Numerous N-S ridges occur in the NW. ¼ of Redford, with bars to the south at a somewhat lower level. At Sand Hill, just north of the center of the township, two prominent sand ridges are found rising to 640 and 660 above sea level, evidently due to wind action. In passing around the peninsula formed by the Detroit moraine the same phenomena are noted as for the Wayne beach. Sand ridges, with more or less gravel, occur both north and south of Grand River Avenue, Greenfield township, in secs. 28, 29 and 30. The eastern half of the township is spotted with beach and bar ridges in Palmer Park, about Highland Park and continuing into Hamtramck township as shown in Pl. X.

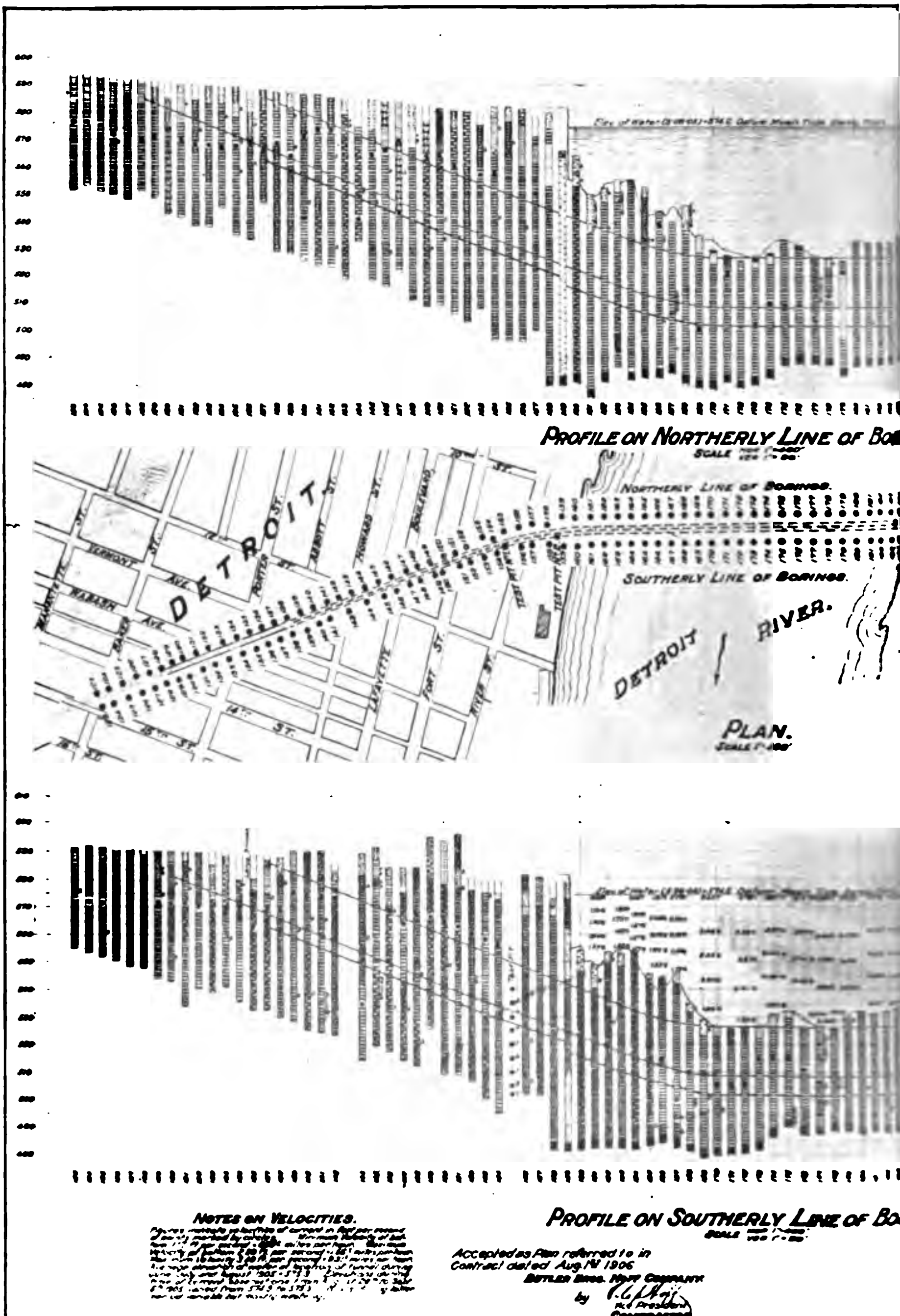
Near Willow and Waltz in southwestern Huron township some conspicuous NW. to SE. sand ridges are found whose elevation is too low for the Grassmere and somewhat high for the next lower beach of the series:—the Elkton. These rise to heights of 620 to 625 feet above sea level and are apparently the result of wind action. The eastern half of Huron township is more or less sandy but shows little suggestion of ridging. This condition of the soil and surface extends into northwestern Brownstown where ridging becomes noticeable in secs. 9 and 16, with elevations ranging from 606 to 612 feet. This belt of sand ridges passes northward through Taylor township, entering Dearborn township in sec. 33, not well defined at first but becoming more so toward the village of Dearborn. The profile of the electric railway here shows a crest 600 feet broad, reaching an elevation of 617 feet, with an abrupt slope on the eastern side and a much less one to the west. Northward from Dearborn, there is a belt of sand about two miles broad, with short, discontinuous ridges passing through secs. 21, 16, 9 and 4, becoming more and more indistinct as the old water line passed up behind the Detroit moraine. A gravel-sand ridge starts in the NE. corner of sec. 1 and continues into the eastern half of sec. 36, Redford township, rising to 621 feet. Turned eastward by the moraine, a nearly continuous ridge may be traced through the lower strip of sections of Greenfield township, crossing northeastern Springwells and entering the city of Detroit. It crosses

Warren Avenue southeastward and disappears as a ridge between Buchanan and Poplar streets, at about 17th Street, but with patches of sand still showing to the southeastward for a mile further toward Grand Circus Park. In passing around the point of the Detroit moraine, there was too much wave action for the formation of a beach ridge and there remains now only a cut shelf in the till slope, with the elevation of 605 to 615 feet, best seen on Joseph Campau Avenue, between Campau Park and Monroe Street, but also on the other neighboring streets looking northward from Monroe. Upon the eastern side of the moraine, the sand appears again to the northward and northeastward from Elmwood Cemetery, for the most part scattered but in places ridged. Parallel with Gratiot Avenue, but one to two miles to the eastward, the beach may be traced northeastward across Gratiot township leaving the county in sec. 6.

The next stage in the general recession of the lake waters is marked by a rather poorly defined beach line, the correlative of one of the Algonquin beaches, but at a lower level. The most northerly strip is to be designated the First St. Clair beach by Taylor in his forthcoming monograph and was formed about the margin of a lake which was the ancestor of our present Lake St. Clair. This lake received the drainage from Lake Algonquin during a considerable portion of the life of the latter and drained southward, as at present, into Early Lake Erie. The old water level is indicated in the northeastern corner of Gratiot township as a slight cut of one to two feet in the surface clay, entering the county just east of the 600-foot contour, passing southward and curving to the west before reaching Mack Avenue. As it approaches Connor's Creek, in the southern part of Gratiot, it shows some sand, apparently contributed by the creek itself during this stage. In the village of St. Clair Heights, some sand ridges mark the level, running southwestward towards the river just west of the Waterworks, crossing Jefferson Avenue and continuing parallel with it on the river side as a rather steep bluff entirely around the Detroit moraine, and causing the abrupt descent to the river.

In the east central part of Grosse Point township the Emmet moraine had its crest above the water level at this stage, forming a small island and having a gravelly beach formed upon its lakeward side. This moraine seems to have protected the shore line to the west from wave action and explains the weak character of the beach there formed.

Before reaching the present Michigan Central depot, foot of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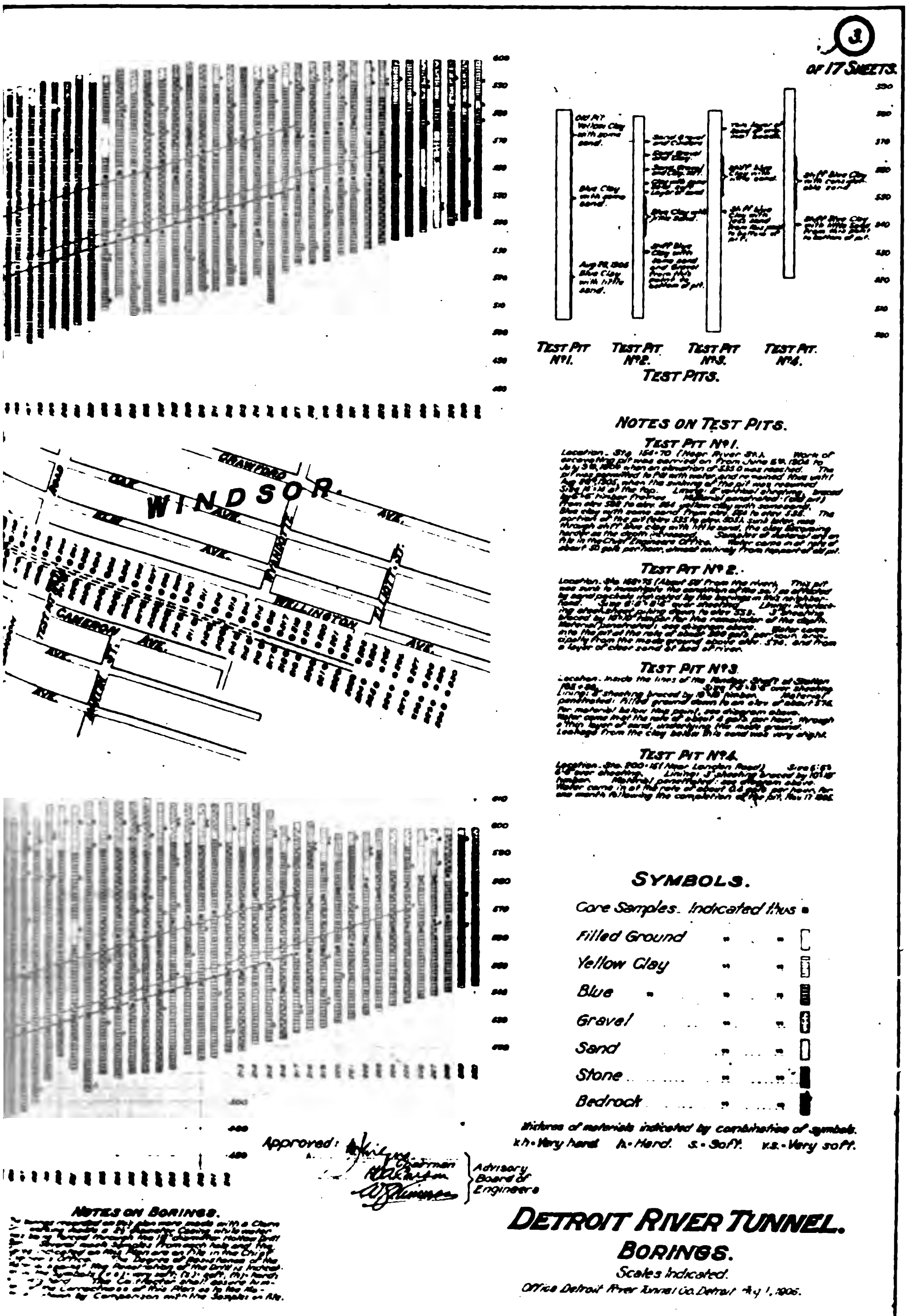


THE STRUCTURE OF THE WISCONSIN TILL.

Third Street, the cut bluff crosses Jefferson Avenue to the northwest at about Wayne Street, curves to the north of the Union depot and continues westward on the north side of Fort Street. This cut bluff along the Detroit River front suggests rather vigorous current action as the waters entered Lake Rouge and marks the early banks of the then very short Detroit River, or perhaps more appropriately the Detroit Strait. Near the Boulevard, running back from the river, sand again makes its appearance between West Detroit and Ft. Wayne and numerous well defined ridges appear with a general east-west trend. These furnish the site for Woodmere Cemetery and a prominent sand-gravel ridge, one-half to one-eighth of a mile wide and some 15 to 16 feet above the river, which determined the location of Ft. Wayne and gave it command of the water. West of Rouge River some of this sand continues into Springwells township and much of it is found upon the Ontario side opposite, extending back two to three miles from the river, supplied mainly, Taylor thinks, by the distributaries breaking through the Detroit moraine and sweeping along the sand and gravel into the more quiet waters of Lake Rouge. This beach is the correlative of the First St. Clair; that is, it was formed simultaneously with it, as well as with the Algonquin further north, and will be named by Taylor the First Rouge beach. The shore line of this lake curves to the south through the western part of Ecorse township, turning eastward in sec. 31, because of the moraine there encountered, and continuing southward to the west of Trenton. The moraine upon which this village stands is high enough to have received the beach but may have been simply wave cut, either during the life of Lake Rouge or subsequently. In Monguagon township, sandy streaks occur at the right elevation in secs. 11, 14, 23, 26 and 35 and further west in and about Flat Rock on the Huron. Sand, probably of the nature of delta sand carried by the river during this stage, was deposited along the valley down to its present mouth. Grosse Isle was also an island at this stage, although more completely submerged and received a low gravel ridge about the northern end where the waves of the lake were strongest.

The last beach, before the present water level was reached, lies only some 6 to 7 feet above the present level (elevation about 582 feet), so near that it might readily be regarded as belonging to the modern series. It is more or less scrappy in character so that it can not be followed continuously, in some places represented by a cut bench, in others by a low sand or gravel ridge, usually quite near the present water margin, but where the land is low, more

distant. Upon the Nellist map, the beach is marked as a "transition beach", is now regarded by Taylor as marking the level of the waters in this region during the life of Lakes Nipissing and will be known as the Second St. Clair and Second Rouge respectively. Formed in the bodies of water into which these lakes drained, this beach has been from the first at a lower level and can not with propriety be termed the "Nipissing," but it is its correlative. Although there has been considerable recent cutting along the western shore of Lake St. Clair, portions of this beach are preserved here and there between the lake and the main highway in Grossepoint township. At Milk River Point, just over the north county line, the northern end of the Emmet moraine shows a very pretty cut bluff referable to this stage of Lake St. Clair (see Pl. XVI, B) its preservation being due, apparently to the concentration of boulders along the shore by wave action (Pl. XI, B).

Southward from Grossepoint Farms, it leaves the river and swings to the southwestward about a mile back from the river in passing Windmill Point, continuing as a sand ridge through Cottage Grove and Fairview. The portion representing the bank of the river during this stage has been destroyed, either by its subsequent work, or by the grading and artificial structures along the river front. The Second Rouge beach, however, appears in the western part of the city, best seen at Ft. Wayne as a cut bluff and in Delray and on Brady Island as a ridge. It follows along the highway across Ecorse township, now on one side and now on the other, as a pretty well defined and rather continuous sand ridge which seriously obstructs the drainage of the region. In Monguagon township, the moraine throws the beach close to the river where the most of it has been destroyed. Upon the islands in the river, where protected from recent wave and current action, traces of this stage of the water level may be here and there detected. It shows as a cut bluff along the southwestern corner of Grosse Isle and as a gravel ridge on the mainland opposite in the NW. 1/4 NW. 1/4 sec. 1, Brownstown township.

Deltas. During the various lacustrine stages just described, the streams were at work bringing detritus from the higher portions of their basins and, upon the checking of their velocity, depositing it in the more quiet lake waters. Especially active during the stages of flood, year after year deposits were formed about the mouths of these streams, of the same age as the correlative beach, changing the topography and soil and furnishing a rough measure of the time involved in the lake stage itself.

So far as we may judge from the map of the Coast and Geodetic Survey, Huron River at the present stage has not formed a delta

over two square miles in area, while the same stream during the Lake Arkona stage formed a delta some twenty times as large. Climatic conditions, were of course, sufficiently different to vitiate any definite conclusions that we might draw from these facts. During the Maumee stages, only the Middle Branch of River Rouge was in existence and it emptied into this series of lakes just north of Plymouth, but deposited only a relatively small amount of sand and gravel, owing partly to the small size of the stream and the relatively short duration of the lakes. During the life of lakes Whittlesey and Arkona, much more work was accomplished by this stream, but, owing to the rise of water from the latter to the former, the work during each stage can not be distinguished. Gravelly sand extends from the northeastern corner of Canton and the northwestern corner of Nankin townships, northward across Plymouth and Livonia, to the county line, apparently distributed shoreward by waves and currents. This deposit extends southeastward for some five miles into Livonia and covers an area of some 28 to 30 miles, supplying the materials for the beach ridges and bars of this region. The surface elevation of this great fan-like deposit ranges from 730 feet, just in front of the Whittlesey beach to about 660 feet above sea level and an inspection of the topographic map shows how these contours have been deflected eastward as they cross this deposit. The well records of the region indicate that the beds of sand and gravel reach a depth of 12 to 15 feet, before the clay is struck, thinning towards the margins of the area.

Southward a very similar, but still larger, delta was formed during the same stages of the glacial lake waters by Huron River of that time. This delta covers the western and southern portions of Van Buren township and the northern two-thirds of Sumpter, comprising a gravelly-sand area of 42 to 43 square miles within the limits of Wayne County, and attaining a maximum thickness of some 20 feet. In a NE.-SW. direction, it extends from Denton to West Sumpter and eastward as far as French Landing. The more or less well defined character of the Arkona beaches which rest upon the Rouge and Huron deltas, indicates that these deposits were formed mainly during the life of the Arkona series of lakes, otherwise they would have been deeply buried in the deposits of Whittlesey time. During the latter stage, the Huron emptied into the lake with an estuary-like mouth and much of its delta gravel and sand was deposited before actually reaching the lake. The result of this is that the delta is continued up the present valley of the Huron as a well defined terrace. Very little in the way of delta deposit seems to have taken place during the subsequent lake

stages, the material having been mainly sand and this was largely worked over into bar and beach ridges and subsequently into dunes by the wind. Were these deposits removed we should undoubtedly find a dressing of sand remaining to mark the location of the mouths of the various streams entering the lakes.

Distributaries. A very interesting series of "distributary channels" has been described by Taylor in the forthcoming monograph previously noted. When the waters were dropping from the First St. Clair stage, during the life of Early Lake Algonquin, the Detroit moraine is conceived to have served as a very temporary dam, over which the waters cut their way at several points simultaneously, digging channels and depositing the sand and gravel in Lake Rouge. Taylor recognizes two such channels in Detroit and others were probably formed and destroyed in the present bed of the river, since the permanent flow would probably be in the direction of the larger. Congress Street lies in the axis of one of these channels, east of Woodward, and Baker and Labrosse streets to the west of Grand Circus Park. The great quantity of sand and gravel between West Detroit and Ft. Wayne and between the Boulevard and the River Rouge (see Pl. X), with an elevation of 585 to 595 feet, is believed to have been so deposited and only a minor portion of it by the present Rouge (see Pl. XVII, A). Near Trenton, Grosse Isle (Pl. XVII, B) and Amherstburg a much more complicated system of such distributaries has been mapped by Taylor and are being described by him. Their course in this region seems to the writer to have been determined very largely by the morainic ridges of the Grosse Isle moraine, hence there was comparatively little erosive work done and little or no deposition about their mouths. The water found and occupied the depressions between these morainic ridges in the lower Detroit River region instead of carving them entirely from the till plain. According to Taylor's interpretation the till ridges are *destructional* features, while the writer is compelled to believe that they are really *constructional,* and modified more or less by current action.

Lake deposits. Aside from the gravel and sand deposits just described, the waters of the glacial lakes deposited comparatively little sediment over their floors. In many places, the glacial till comes quite to the surface and boulders and even cobbles are found resting upon the surface without cover. Theoretically there must have been some deposit throughout but it seems to have been so scanty in amount over much of county that it has either been removed by surface erosion, or incorporated into the few inches of surface soil. Just west of the Detroit moraine, however, in Springwells township, a considerable deposit was put down in the former

depression, reaching a maximum thickness of some 40 feet, but thinning rapidly from this as a center. This gave rise to a finely laminated clay, the laminae being sometimes as thin as .5 millimeter, generally free from pebbles or boulders, and utilized for many years in the manufacture of brick. The pebbles and boulders that do occur have probably been transported on floating ice, while the clay represents the fine sediment, originally of glacial origin, that was slowly transported to the deeper water before settling to the bottom. Freshets and exceptionally heavy wind storms, by which wave action about the shore lines would be increased, would contribute unusual supplies of sediment to the deeper and more quiet water and successive layers would be deposited in very regular, horizontal laminae. Small irregular concretions, of lime carbonate, iron and clay, known locally as "clay dogs", occur in some of the beds. These have formed where they are now found by the segregation of the ingredients, probably while the deposit was fresh and moist. They are not abundant enough to seriously interfere with the utilization of the clay in the manufacture of brick and tile. The surface elevation of this lake clay deposit is about 585 to 590 feet above sea level and the workable portion of it covers four to five square miles, gradually thinning in all directions and merging into the glacial clay. When wet it is decidedly plastic and sticky and in the spring gives rise to roads that are well nigh impassable for teams and automobiles.

In the deeper pits from which brick clay is being taken (as at Haggerty's, Daniel's and Clippert's), three quite distinct beds may be noted, distinguished by their color and rather sharply separated. Beneath from 6 to 12 inches of surface soil, there occurs a yellowish-brown layer from 2 feet to 4½ feet in thickness. Beneath this occurs a layer in which the iron ingredient has assumed a slight reddish tinge, ranging in thickness from 3 to 5 feet, giving out to the eastward, or becoming indistinguishable from the upper. Below this lies a bluish bed, extending apparently to the bottom of the deposit. It is conceivable that these three beds were formed under slightly varying conditions during the lifetime of a single glacial lake, or that they represent the deposits of three successive lakes such as the Lundy, Warren and Wayne. Somewhat confirmatory of this latter view is the fact that there is an average increase in the amount of sand towards the top as though the water was becoming shallower during deposition and the shore line had drawn nearer to the region. The following analyses of these clays were made for this report in 1902 by Elmer E. Ware, under the direction of Prof. E. D. Campbell of the University of Michigan.

TABLE IX.—ANALYSES OF WAYNE COUNTY LAKE CLAYS.

Chemical ingredients of clays.	General description of samples.														
	Blue or deepest bed.			Red or middle bed.			Upper or yellow-brown bed.								
	Daniels & Bros. 14½ ft. from surface.	Clippert & Bros. 14 ft. from surface.	Haggerty & Son. 12½ ft. from surface.	Daniels & Bros. 7 ft. from surface.	Clippert & Bros. 7 ft. from surface.	Haggerty & Son. 5½ ft. from surface.	Lonyo Brick Co. 5 ft. from surface.	Proctor Bros. 5 ft. from surface.	M. Downey. 5 ft. from surface.	Daniels & Bros. 2½ ft. from surface.	Clippert & Bros. 2½ ft. from surface.	Haggerty & Son. 2 ft. from surface.	Lonyo Brick Co. 2½ ft. from surface.	Proctor Bros. 2½ ft. from surface.	M. Downey. 2½ ft. from surface.
Number of samples	3	6	9	2	5	8	10	12	14	1	4	7	11	13	15
Silica (SiO_2)	57.55	57.58	55.53	57.18	55.86	57.75	66.19	65.75	69.50	71.32	56.16	74.77	67.06	58.42	59.46
Alumina (Al_2O_3)	13.42	13.63	10.89	16.04	15.24	14.75	12.78	15.04	14.84	12.73	10.95	8.32	16.78	13.41	14.88
Ferric oxide (Fe_2O_3)	3.92	3.62	4.30	5.26	4.50	3.70	5.18	5.26	4.92	4.88	3.32	3.02	4.30	4.70	4.40
Calcium oxide (CaO)	7.40	6.94	9.23	6.46	7.10	5.92	3.37	3.10	1.92	1.70	10.24	3.04	1.70	5.86	5.18
Magnesium oxide (MgO)	5.96	4.68	5.36	4.60	5.05	4.68	3.58	3.05	2.09	2.19	4.86	2.52	2.30	4.46	5.01
Loss on ignition*	11.43	11.18	12.51	10.07	12.23	9.90	4.67	6.85	4.42	4.67	13.95	5.07	4.98	10.08	9.38
Sulphuric anhydride (SO_3)	.64	.65	.80	.01	.06	.06	.13	.06	.16	.13	.04	.05	.06	.04	.11
Sodium oxide (Na_2O)	....	....	....	....	....	....	....	2.45	....	....	....	1.85	2.69	....	....
Potassium oxide (K_2O)	....	....	....	....	....	....	....	.74	....	....	....	1.54	.87	....	....
Difference	−.32	+1.72	+1.38	+.38	−.04	+3.24	+4.10	−2.30	+2.15	+2.38	+.48	−.18	−.74	+3.00	+1.58
Totals	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

*This includes combined and hydroscopic water, organic matter, carbon dioxide, alkaline chlorides, etc.

Of the various brick plants from which the samples were taken that of L. D. Haggerty and Son is the most westerly, being located just north of Michigan Avenue, in Springwells township, at the Pere Marquette crossing. George H. Clippert and Brother and Jacob Daniels and Brother, come next in order to the south of Michigan Avenue, 1/4 and 1/2 miles respectively. The other three have their brick manufactories near the avenue; Lonyo-Brick Company 1 mile east of the Pere Marquette, Proctor Brothers 1 1/2 miles east and M. Downey 2 miles. Aside from the composition of these economically important clays the above table shows several things of interest. The average amount of silica present in the 15 samples analyzed is 62.01% and of the alumina 12.60%. The two lower, and hence oldest beds, have an average of 56.91%. The ferric oxide in the entire series averages 4.35% and shows no marked differences in the samples selected from various depths, owing to the fact that this compound is insoluble in ordinary water. The case is quite different, however, when we examine the varying percentages of calcium and magnesium oxide and the sulphuric anhydride. These oxides listed are present in the clays as carbonates mainly and the anhydride is very probably combined with a relatively small amount of calcium oxide to form the calcium sulphate. These are all moderately soluble in ordinary water and appear to have been partially leached from the uppermost bed, since it gives an average of 4.01% of calcium oxide, 3.34% of magnesium oxide and .09% of sulphuric anhydride, as compared with 7.17%, 5.05% and .37% respectively in the middle and lower beds. The application of the dilute acid test in the field shows also a marked difference in the reaction, in harmony with the above conclusions. Since the carbonates of sodium and potassium are so readily soluble and are reported only from the upper beds, it seems likely that these akaline elements are in the form of silicates. Their absence in 12 of the samples would seem to indicate that they had not been determined in the analyses.

In Grosse Point township and within the city limits of Detroit, other less extensive deposits of similar lake clays are encountered, lying to the eastward of the Detroit moraine. In tunneling beneath the river from the Waterworks towards the head of Belle Isle in 1902, a cat tail bog, evidently of rather recent origin, was penetrated to a depth of 15 feet. Beneath this lay a bed of brownish lake clay carrying shells and occasionally glaciated, crystalline boulders. When visited by the writer in March, 1902, this bed had been penetrated to a depth of 25 feet below the river level. Exca-

vations upon the grounds to the north showed that the deposit was of limited extent. In the Ecorse salt shaft, there was encountered 4 feet of muck, 2 feet of mucky clay and 4 feet of mottled (brown, yellow, blue) clay with shells. At the Woodmere salt shaft, there was blue glacial clay from the surface soil to bedrock.

A shallow deposit of lake clay is found in the vicinity of Leesville, on Gratiot Avenue, that was at one time extensively used in the manufacture of brick. The deposit averages only 3 to 4 feet in thickness, consisting of blue and yellow clay, free from stones, and extends for a distance of a couple of miles along the avenue. The area is rather difficult to trace from its surface exposure but appears rather narrow and much more local than the Springwells deposit.

CHAPTER IV.

PHYSICAL GEOGRAPHY (Continued).

SURFACE DRAINAGE.

Stream development. Within the limits of Wayne County, the present surface streams had their origin and began their development only after the waters of Lake Maumee had receded to the level of Lake Arkona, where they appear to have halted for a relatively long period. This recession of the water was practically the same as a general uplift of the lake bottom and there came into existence a large number of short, straight, approximately parallel, stream courses, devoid of tributaries, flowing down the eastern slope of the Defiance moraine and across the narrow strip of bared lake bed. Such streams are known in the physiographic language of today as "consequent streams", their course being in *consequence* of the surface slope at the time of their development. The surface topography of the region in question was due in large part to the ice sheet itself; to a less extent to the work of the lake waters both in their destructive and constructive action. A good example in miniature of the character of streams above referred to is shown in the accompanying Pl. XVIII, A, which represents an unusually heavy deposit of wind-blown sand exposed for the first time to a heavy shower.

Irregularities in the hardness of the material being cut into by the streams would cause lateral deflection here and there and the streams would begin to meander. Occasionally, the divide between two neighboring streams would be destroyed at some point by the more active and it would thus draw off the upper flow of the weaker neighbor, "capturing" or "beheading" it. Similar results would also be accomplished with the help of small tributaries developed along the side, or about the head of the more vigorous streams and there would be developed gradually a smaller number of drainage systems, nature favoring the more aggressive. Deep gullies were cut in the till in the upper, steeper part of their courses and the material so derived was deposited as bars and flood plains in the more gentle courses, eventually landing in the more quiet lake waters to assist in the formation there of deltas, beaches and bars.

The advance of the water-level from the Arkona up to the Whittlesey stage, some 35 to 40 feet, submerged to this depth the lower courses of the streams then in existence, causing less "fall" and bringing about a sluggish condition known as "drowning". It was as though the entire region had been depressed this amount, so far as the streams themselves were concerned. Something of a similar nature but on a smaller scale had occurred when the water rose from the lowest, or third stage of Lake Maumee up to the second stage. The chief streams of this region to be so affected were the Middle Branch of the Rouge and the Huron. The latter had entered Wayne County during the Arkona stage at Rawsonville but when the rise of water came had its mouth pushed westward into Washtenaw County, some two miles, forming an estuary in which the deposits of Whittlesey time found lodgment. When the level of the glacial waters finally dropped to that of Lake Wayne, the streams were revived, "rejuvenated" as it is termed, flowing to a lower level, with quickened velocity and increased cutting power. The normal direction of increase in the length of a stream is headward, as it works its way farther and farther back towards its limiting divide, thus enlarging its basin and increasing its drainage area. The streams of Wayne County have made but little headward growth but, relatively speaking, have greatly extended themselves mouthward, giving rise to a type of stream somewhat difficult to classify satisfactorily. Since most of the streams are still engaged in deepening their beds throughout a considerable portion of the year, we should look upon them as "youthful" and still they show well developed flood plains and mature meander loops.

The rise of the water from the Wayne to the Warren stage, some 25 feet, again brought about the same drowned condition of the lower courses of the streams, to be presently followed by a series of rejuvenated stages as the waters dropped successively to the lower levels. Not until the close of Lake Lundy did the three branches of the Rouge unite into a single stream, thus bringing these three systems into a single one. As the waters subsided, the Huron received very little additional surface drainage, but considerable seepage along its banks from the extensive sand and gravel deposits contiguous in Van Buren, Romulus, Sumpter and Huron townships. Only during the life of Lakes Nipissing and of the present system have the streams along the eastern margin of the county been in existence and that they are perceptibly younger is indicated by their direct courses and general absence of tributaries. Owing to their youth, lack of fall and limited drainage

areas, they have not reached the level of ground water throughout much of their courses and hence are only "intermittent streams" in these portions.

During the stage of Lake Algonquin, when the St. Clair outlet was not in commission, the streams of the county were all flowing to much lower levels than at present and were permitted to cut channels much deeper than would now be possible with the sluggish condition of the water about their mouths. When the drainage into the St. Clair was again established the level of the water rose, entering the river channels, submerging the banks and bringing about the present drowned condition of the modern streams.

Drainage systems. If one attempts to classify the present drainage systems of the county, the most natural basis of such classification would be the body of water into which the drainage is conducted; as Lake St. Clair, Detroit River and Lake Erie. Upon such a basis, only the short and relatively unimportant Milk River would constitute the first division; the Huron and Swan Creek would make up the Lake Erie, or third division, while the remaining streams would be included in the second, or Detroit River division. Instead of describing the various drainage systems of the county in this order it will be found more interesting to the general reader to take them up in the order of their appearance and subsequent development. In the first to be presented, we may then look for the evidences of relative age and contrast its stage of development with the youthful members of the series, our basis of classification then being relative age. The rather anomalous condition will then appear that these streams are all *older* than the bodies of water into which they now empty.

The oldest and largest drainage system to be developed within the county is that of the Rouge,[1] with its Eastern, Middle and Lower branches which unite into a single trunk stream just east of Dearborn. The area drained by this stream and its branches constitutes its *basin* and this comprises approximately one-half of the county. When the ice withdrew from the Defiance moraine and allowed the waters of the glacial Lake Maumee to work their way northeastward between this moraine on the west and the retreating ice-wall on the east, a series of gullies was started upon the eastern slope of the moraine; which, although separate and independent at first, eventually gave rise to the three branches of the Rouge in Oakland, Wayne and Washtenaw counties. The drainage from the *western* slope of this moraine in Northville and Ply-

1 This name presumably alludes to the color of the sediment with which the stream is generally charged. Instead of being *red* however, the color more frequently seen is yellowish-brown.

mouth townships, combined with that from portions of the Northville and Ft. Wayne moraines, which drainage had been to the southwestward while the ice front stood at the Defiance moraine, was now reversed, because of its finding a break in this moraine just south of Northville, and this gave the Middle Branch from the start an advantage of many square miles of drainage area over the other two branches. This advantage has been retained to the present day, accounting for its greater activity in the way of delta formation in the past and its greater importance today as a source of water-power.

This Middle Branch of the Rouge takes its origin in the swampy areas lying in the northern half of Salem township, Washtenaw County, the crest of the Ft. Wayne moraine serving as the divide between it and the upper Huron basin. Its general course across Salem township is southeastward, entering Plymouth in sec. 19 and thence following the course of the old drainage channel noted, but in reversed direction, for five miles to the northeast, cutting through the Defiance moraine and receiving from the region to the north the drainage from Ingersoll Creek and its tributaries, lying between the Defiance and Northville moraines. From Northville, the general course of the stream is southeastward, following the general surface slope, but turning eastward in the NE. 1/4 of Nankin and NW. 1/4 of Dearborn townships. Small tributaries, more or less intermittent in character, are received along the way. At Pikes Peak, it receives its largest tributary, Tonquish Creek, which starts with three branches heading along the eastern slope of the Defiance moraine, draining southern Plymouth, northern Canton and northwestern Nankin townships. In the latter township, this creek is deflected to the northeastward by the heavy sand deposits associated with the Wayne beach, otherwise it would have drained to the Lower Branch of the Rouge. Within the limits of the county, the average fall in the Middle Rouge is about 11 feet to the mile, measured along the valley, and not with the stream, as far as the junction with the other branches. Water-powers are utilized at Northville, between Plymouth and Waterford and at Pikes Peak. During times of flood from heavy rainfall, or rapid melting of snow, the stream becomes a torrent, deepening its bed and broadening its valley here and there by lateral cutting. Successive deposits at such times upon either side of the main current have built flood plains of river silt to a height of several feet above the ordinary stage of the water. As the stream swings from side to side these valley deposits are successively destroyed in one direction and slowly restored upon the other, so that the flood plain

in any cross-section of the valley is not uniform in height. During times of flood, a deposit often takes place upon either side of the main channel just where the current is suddenly checked by the more sluggish water covering the valley flat. There may thus be built up a low ridge of sand, or silt, higher than the general level, upon either side of the main channel and roughly parallel with it, to which the term "natural levee" is applied. The flood plains are narrower and generally higher above the water in the upper portions of the valley and broader and lower as one descends the stream. At Plymouth, the Pere Marquette Railway crosses the Middle Rouge at right angles and the profile shows the valley there to be 1300 feet in breadth and that the banks have an elevation of 722 feet above sea level. The general level of the flood plain is 693 feet, making the banks above this plain about 29 feet, or some 35 feet above the water. One mile north a similar profile gives the same breadth to the valley, with 40-foot banks and a flood plain 5 feet above the bottom of the bed.

The Northern Branch of the Rouge is essentially similar to that just described although shorter and with smaller drainage area. It takes its origin in the NW. ¼ Southfield township, Oakland County, pursues a generally southern course across Redford township, owing to the Detroit moraine, uniting with the Middle Branch in the SE. ¼ sec. 10, Dearborn; just after the close of the first stage of Lake Lundy. In Southfield township, it is deflected to the southwestward for a few miles by the extension of the Birmingham moraine and at the village of Southfield furnishes water-power. From the Whittlesey beach the average fall to Dearborn is about eight feet to the mile, and that of the Middle and Lower branches from the same point of reference, flowing farther but with less total fall, average the same. Within the limits of the county, however, the fall in the North Branch is much less, only about 2½ feet to the mile, it having succeeded in cutting most of its bed below the 600-foot contour. In these measurements, the length of the valley itself was taken; with the actual length of the stream, the fall would average considerably less. The Pere Marquette profile furnishes a cross-section of this branch at Oak, in southern Redford township, showing the valley to be 1500 feet across, with banks 35 to 36 feet in height. Towards the north county line the banks become less in height, reaching 18 feet, and also southward in Dearborn township, where they are 25 to 30 feet. Small, more or less intermittent, tributaries are received, mainly from the eastern portions of Southfield and Redford town-

ships. One larger double tributary is received from the west, just south of Bell Branch, which drains western Redford and the greater portion of Livonia. In his studies upon the lateral erosion of Michigan rivers, Jefferson included the three branches of the Rouge and notes the general inactivity of this North Branch when compared with the other two, so far as lateral cutting and deepening of the bed are concerned.[2] The former flood plain, some 10 to 15 feet above the water, has become a terrace, through the deepening of the bed and is no longer within reach of freshet waters.

The general course of the Lower Rouge is rather direct and easterly, turning in the last seven miles to the north of east, apparently deflected by the heavy sand deposits of the Wayne and Grassmere beaches. Its natural course was southeasterly across Romulus and Taylor townships to the Ecorse basin. It originates upon the eastern slope of the Defiance moraine, in the NE. ¼ of Superior township, Washtenaw County, is deflected to the southwestward by the Whittlesey beach near Cherry Hill, Canton township, receiving a succession of short tributaries from the moraine. In its course, it crosses southern Canton, Nankin and Dearborn townships, receiving a few simple tributaries. Throughout the main part of its course, it shows a well defined flood plain which receives deposits once or twice a year, at the times of overflow. The Pere Marquette profile, one-half mile west of Wayne, gives a breadth to the valley of 900 feet, with banks 27 feet above the bed and a flood plain 7 to 9 feet above. During ordinary stages of the stream the amount of water is slight but at flood it fills its valley from bank to bank, a muddy torrent (Pl. XVIII, B). The relative amount of cutting upon each of its banks was made the subject of study by Jefferson and his assistants in 1906 (*loc. cit.*, pp. 337 and 338). The stream was carefully studied for a distance of 13.3 miles and the amount of recent cutting of the banks determined by pacing. It was thus found that this cutting, having a tendency to widen the valley, amounted to 3182 paces upon the right, or southern bank, as compared with 1225 paces upon the opposite bank. These bare strips of bank were designated by the Scottish term "scaur" (pronounced *score*) and were found to equal about 10% of the total length of bank. The Middle Branch was similarly studied for a distance of 16½ miles, giving 1008 paces for the right bank and 299 paces for the left, the amount of scaur being but 2%. This effect may be assumed to be due to the direction of rotation of the earth upon its axis, which would the-

2. Lateral Erosion on Some Michigan Rivers: Bulletin of the Geological Society of America, Vol. XVIII, 1907, p. 341.

oretically tend to force the right bank against the stream, or to the tilting of the crust of the earth in this region which would tend to deflect the water of these particular streams against the right bank.

These three branches of the Rouge remained distinct until Lake Lundy dropped from its first to its second stage which allowed the North and Middle branches to unite into a short trunk stream. This seems to have delivered more or less sand to the lake which was worked into beaches, bars and dunes about Dearborn. The fall of the waters from the second stage (Elkton) to that of Lake Rouge allowed the Lower Branch to join the other two just east of Dearborn and the formation of the main stream was effected. The valley here is 3,000 feet across, with broad flood plain 6 to 10 feet above the water and banks about 20 feet above the plain. The stream itself is 40 to 50 feet across and some 8 to 10 feet deep, sluggish and generally more or less clouded with sediment. The fall is only about four feet in 7½ miles, or but slightly over six inches to the mile upon an average. The last four or five miles, however, are almost without current, except as the surface water is moved by the wind. The banks have grown lower with each mile and finally become submerged owing to the drowned condition of this section of the stream. (As types of drowned streams see Pl. XIX, A and B). At Oakwood, there is received from the north a small tributary known as Campbell Creek, draining the western slope of the Detroit moraine, except the small portion in the northeastern corner of Redford township which drains into the North Branch. This stream was known in an early day and still later as the East Branch of the Rouge, the short tributary at Woodmere being called Knaggs' Creek. The *drowning* continues for about a mile and one-half up this stream also. Near the mouth of the main Rouge, the stream curves to the north and east going about a mile out of its way to reach the river. An artificial canal about one-half mile long was constructed direct to the river, cutting off a marshy tract nearly one-half a square mile in area known as Brady Island. According to information secured from Pres. J. D. Hawks of the Detroit and Mackinaw Railway, this canal was built in 1888 by the River Rouge Improvement Company, 2887 feet in length. It was originally intended to be 60 feet in width by 12 feet in depth, but was not fully completed after it was discovered that there was sufficient current to continue the excavation, the water entering from Detroit River through the old mouth and passing out through the canal. A surprising feature of the lower portion of the main stream is the depth in mid-channel which is out of all proportion to the present amount of current and to be

accounted for only on the theory that the stream at one time flowed to a lower level. The lake survey chart shows soundings four miles back from the mouth, ranging from 12 to 21 feet and averaging (30 readings) 15.8 feet. It is interesting and significant that the older maps show ship yards located at Woodmere, not only on the main stream but also the tributary, some four miles up from the mouth, at which lake going vessels were formerly constructed and repaired. In an official letter to the British Government in 1800, allusion is made to these yards as a menace, in that they furnished a sheltered site for the building and arming of lake vessels.[3] In 1812 the Brig Adams, of 14 guns, was here for repairs.[4] Such is the intimate relation between geological history and political and economic affairs. This submerged condition of the river banks is occasionally responsible for a tragedy, since boys wading along the banks may suddenly find themselves beyond their depth.

Although Huron River, in its upper course, considerably antedates the Rouge and its various branches, it did not enter the county permanently until after the fall of Lake Whittlesey. It takes its origin in the southern part of Springfield township, Oakland County, in Big Lake (elevation 1017 feet). A small pond with an elevation of 1020 feet lies some two miles to the southwest and is connected by marsh with Big Lake. It is quite probable that at times more or less flow would take place and that this pond is probably to be regarded as the true starting point of the Huron. The Huron River has a length of some 80 miles measured along the valley (probably three times this following the bends of the river) and, according to the estimate of the Hydrographic Bureau of the United States Geological Survey, has a drainage basin of about 1060 square miles, only a small portion of which lies in Wayne County. Its general direction of flow is southwestward, through a series of lakes in Washtenaw County, as far as Hudson Mills where it turns to the southeast, entering Wayne at Rawsonville on an easterly course as far as French Landing, apparently deflected from its natural course by the delta deposits in Lake Arkona which lie mainly southward. At this place, the stream turns southward and then southeastward across Huron township to Flat Rock, from which place it forms the boundary between Wayne and Monroe counties to its mouth in Lake Erie. In the vicinity of Flat Rock and Rockwood, the river has shifted its channel slightly in its meandering over the old lake bed. From Base Line Lake, the last in the series, there is a fall of 279 feet to Lake Erie, or an average of 5$\frac{1}{6}$ feet to the mile, causing an active flow, numerous

3. Michigan Pioneer and Historical Collections, Vol. XV, 1889, p. 14.
4. *Ibid*, p. 64. See also Lossing's Pictorial Field Book of the War of 1812, 1869, p. 265.

rapids and a gradual deepening of the bed throughout much of this course. From Rawsonville down, the fall is 2½ feet to the mile, upon an average, lessening towards Rockwood and becoming very sluggish toward the lake as in the case of the Rouge. The lake chart shows depths in mid-stream of 12, 10, 16, 11, 11, and 13 feet (average 12 feet) and still greater depths towards Rockwood were reported by residents. A small delta, covering about two square miles, is indicated in the lake opposite the mouth. Were the level of Lake Erie to be lowered, the stream now revived would cut through this delta deposit and leave it at a higher level as a delta terrace, exactly as in the case of the Arkona and Whittlesey deltas.

The average flow of the Huron at Flat Rock, some 7 valley-miles from the mouth, was estimated by the miller there in 1902, as 200 cu. ft. per second and the estimated minimum flow is placed as 109 cu. ft. per second by Lyman E. Cooley, who made a survey for the Washtenaw Light and Power Company. The estimated minimum flow at Rawsonville is placed by Cooley at 100 cu. ft. per second. Since the year 1903, the Hydrographic Division of the United States Geological Survey has maintained guaging stations at various points along the Huron, in order to discover its maximum, minimum and mean flow and these results have been published in the Water-Supply papers of the Survey (Nos. 129, 170, 206, 244 and 264). From these data, knowing the amount of fall in the stream, it is possible to figure the approximate power that could be utilized. Only temporary guages were maintained at Dover and French Landing, but, at Dexter, Geddes and Flat Rock, observations were made from 1905 to 1910. The data for the station at Flat Rock, are shown in the annexed table and are regarded as accurate and reliable. The gauge was placed upon the downstream side of the left-hand bridge abutment, just below the Metler dam, and was read twice daily by Mr. C. L. Metler. The discharge is given in feet per second, based upon the known size of the cross-section of the stream and the observed height of the water, as read from the gauge. Assuming the size of the drainage basin above Flat Rock to be 1000 square miles, there has been figured the monthly and annual "run off" for the years 1905 to 1910 inclusive. The average for these six years is 8.94 inches, which represents, if we assume an average precipitation over the entire basin of 33 inches, a run-off of 27%. The mean discharge per square mile over the drainage area may be obtained from the table by dividing the monthly, or annual mean, by 1000, the assumed size of the Huron basin.

TABLE X.—DISCHARGE MEASUREMENTS OF THE HURON RIVER, FLAT ROCK.

(Hydrographic Division, U. S. Geological Survey.)

Year and month.	Discharge in second-feet.			
	Maximum.	Minimum.	Mean.	Run off in inches on drainage area.
1904.				
August 6-31	335	89	209	.20
September	580	232	320	.36
October	447	282	351	.40
November	346	262	292	.33
December	543	242	313	.36
1905.				
January	593	346	463	.53
February	644	447	515	.54
March	2,354	580	1,149	1.33
April	1,513	531	957	1.07
May	1,832	495	846	.98
June	2,521	401	1,340	1.50
July	928	357	548	.63
August	814	335	434	.50
September	568	252	389	.43
October	842	324	513	.59
November	1,439	447	612	.68
December	1,476	507	753	.87
The year	2,521	252	710	9.65
1906.				
January (20-31)	2,030	696	1,450	.65
February	1,620	618	967	1.01
March	1,300	390	758	.87
April	1,370	593	938	1.05
May	1,100	447	617	.71
June	898	262	462	.52
July	483	204	277	.32
August	401	204	263	.30
September	242	141	180	.20
October	401	213	259	.30
November	722	282	419	.47
December	1,490	401	859	.99
The year	2,030	141	621	7.39
1907.				
January	2,180	....	1,490	1.72
February	....	....	700	.73
March	1,990	....	1,290	1.49
April	1,360	556	903	1.01
May	1,560	611	909	1.05
June	943	334	610	.68
July	490	220	357	.41
August	403	148	253	.29
September	583	166	306	.34
October	742	368	475	.55
November	654	403	517	.58
December	2,300	270	689	.79
The year	2,300	148	708	9.64

TABLE X.—Concluded.

Year and month.	Discharge in second-feet.			
	Maximum.	Minimum.	Mean.	Run off in inches on drainage area.
1908.				
January	2,060	....	1,030	1.19
February	....	....	1,490	1.61
March	....	....	2,860	3.30
April	2,040	802	1,340	1.50
May	1,570	654	1,000	1.15
June	1,040	240	550	.61
July	345	140	231	.27
August	503	132	309	.36
September	312	116	207	.23
October	452	140	227	.26
November	323	220	258	.29
December	440	250	336	.39
The year	....	116	820	11.16
1909.				
January	668	....	406	.47
February	2,420	....	995	1.04
March	2,030	802	1,240	1.43
April	1,680	625	747	.83
May	2,640	668	1,440	1.66
June	959	368	609	.68
July	312	166	234	.27
August	291	124	208	.24
September	240	148	196	.22
October	280	183	227	.26
November	1,010	240	449	.50
December	1,210	....	588	.68
The year	2,640	124	612	8.28
1910.				
January	1,160	529	719	.83
February	1,480	583	745	.78
March	2,780	757	1,580	1.82
April	1,480	403	688	.77
May	2,280	529	1,080	1.24
June	880	202	509	.57
July	220	140	179	.21
August	230	140	167	.19
September	260	148	200	.22
October	240	202	222	.26
November	312	202	240	.27
December	415	240	293	.34
The year	2,780	140	551	7.50

An excellent water-power at Rawsonville has not been utilized for a number of years, since the destruction of the dam, the only powers now used in Wayne County being at Belleville, New Boston, and Flat Rock. A series of 10 dams, 21 feet in height, is contemplated between Rawsonville and Dexter, to more completely utilize the power in this section of the river, and a storage reservoir of the lake region is being considered, intended to regulate the flow throughout the year. In this way, the damage from floods would be largely obviated and the entire annual flow much more fully utilized. The fall from Rawsonville to the lake is about 71 feet, so that much more power in the county could be procured than is at present utilized.

Upon entering the county at Rawsonville, the banks are 55 to 60 feet high and nearly a mile apart, rising higher toward Ypsilanti and dropping gradually toward the mouth. A series of terraces, marking former flood plain levels, occurs in which the river has incised its bed so deeply that only the lowest is now reached by high water. Across this series of terraces, the river meanders, cutting on the convex side of its loop and filling in upon the concave, but doing comparatively little in the way of broadening its valley. From a study of the breadth of the meander belts of certain rivers, Jefferson finds that the average width is about 18 times that of the stream itself.[5] When the loops become mature "cut-offs" occur, straightening the stream and giving rise to "oxbow lakes" upon the flood plain. At Belleville, 2½ miles from Rawsonville by the valley, a series of terraces occurs, related to the ancient river history. The village itself is located upon one such terrace, some 43 to 44 feet above the river, portions of which also show upon the north side. A section shows 4 to 5 feet of yellow loam and gravel resting on a bed of till. The banks of the river when this terrace was formed are now one to two miles distant and 10 to 12 feet higher. The stream itself at Belleville is 85 to 90 feet broad, with a flood plain 4 to 6 feet above the present water level. Between this and the upper terrace there occurs also an intermediate one about 10 feet above the present flood plain. At French Landing, the main terrace is about 38 feet above the flood plain and the old bank is some 54 feet above the water, the stream being here about 95 feet broad (Pl. XX, A). The elevation of this higher terrace near Belleville is about 678 to 680 feet above sea level and at French Landing, nearly three miles eastward, has dropped to about 665. It was evidently formed during the Lake Warren stage of the glacial lakes and left high and

5. Limiting Width of Meander Belts: National Geographic Magazine, Oct., 1902, p. 380.

dry when the stream was rejuvenated by the waters dropping to the Lake Lundy level.

Near New Boston, the Pere Marquette Railway furnishes a cross-section of the valley, which is seen to be 1800 feet across, the banks being 34 feet above the bed of the stream, which is 602 feet above sea level. The flood plain is 11 to 14 feet above this bed, with traces upon the south side of a terrace 7 to 9 feet higher, or at an elevation of about 625 to 630 feet, and probably representing the remains of a delta formed by the stream during the early stage of Lake Lundy. A section of the terrace shows 4 feet of yellow, gravelly loam, reposing on blue till. At Flat Rock, we have another railway section of the valley, 1500 to 1600 feet across, the stream 130 to 140 feet wide, and banks 20 to 22 feet above the bed. At South Rockwood, the valley is 1400 feet wide, the stream 100 feet broad and 7 feet deep, and the ordinary elevation of the water practically the same as that of Lake Erie. The banks are here 14 feet above the water and the flood plain 7 feet. Upon the northern side of the river, apparently resting upon the flood plain, there is seen a knoll nearly a half mile long, the crest of which is at the same level as the surrounding country. Although the up stream portion carries sand, the body of the knoll is found to be glacial clay and investigation shows that it marks an island in the bed of the river during the Lower Rouge stage, one relatively small channel passing to the north.

From 1823 and for a number of years subsequently, flat boats, of 20 tons burden, came up the river from Detroit as far as the "landing" at Rawsonville, then known as Michigan City. In the fall of 1833, the *Enterprise* was built in Ypsilanti and during the season of 1834 made several trips from Detroit to Ypsilanti, carrying a burden of 150 barrels and propelled by "setting poles". The experiment proved unprofitable and ended with the wrecking of the vessel in December, 1834.[6] The field notes of Hubbard[7] show that he made a detailed survey of the Huron from Ypsilanti to its mouth in August, 1838, mapping the various meanders, noting the soil, banks, timber, breadth and depth of the stream. So far as known, these notes were never published in detail.

Although interesting from the geological and scenic standpoint because of what the Huron is today, as well as because of its economic possibilities, chief interest centers in its development through its various historical stages, briefly alluded to in the

6. History of Washtenaw County, Michigan, 1881, p. 117.
7. These, along with much meteorological material, have recently come into possession of the writer through the courtesy of his daughter Mrs. Frederic Towle, of Detroit.

preceding pages. Very largely through the researches of Leverett, we are able to construct the main outline of this history. While the great Huron-Erie and Saginaw ice lobes were coalescent over the "thumb" and region to the south, (Interlobate moraine) a glacial stream, destined to become the Huron, emerged from between the two lobes near the present site of Hamburg, Washtenaw County, and flowed to the westward, past the present sites of Eaton Rapids, Charlotte and Kalamazoo into a slender glacial lake in front of the Michigan ice lobe known as Lake Dowagiac. From this, the drainage was into the Kankakee River, at South Bend, Indiana; thence into the Illinois and Mississippi.[8] When the ice had receded to a position just west of Ann Arbor (Ft. Wayne moraine) and had uncovered the head waters of the Huron the stream was increased in length as a result and the course of drainage from Eaton Rapids was shifted to the northward, down Grand River nearly to Lansing. Turning westward to Thornapple River and following this valley to the bend near Middleville, the old glacial stream turned southwestward to Kalamazoo and Paw Paw rivers and at Hartford entered the early stage of Lake Chicago. When the ice had withdrawn to about the position of the inner border of the Defiance moraine the discharge to the westward was abandoned, and the Huron was deflected to the present site of Ann Arbor, where it turned southwestward, received a strong tributary moving parallel with the ice margin along the present valley of the Middle Rouge and Fleming Creek, and utilizing a portion of the Saline River valley, received the Raisin and emptied into Lake Maumee while its drainage was by Ft. Wayne into the Wabash. When the ice withdrew from the Defiance moraine sufficiently to allow the water of this stage of Lake Maumee to reach Ann Arbor, the Huron was shortened by this amount, emptying at this place and forming a well defined delta in the northern part of the city at an elevation of 812 feet. With the fall of Lake Maumee to its third, or lowest stage, the Huron reached the lake at Ypsilanti and formed an extensive delta in the eastern part of the city. The rise of the water to the middle stage of Lake Maumee led to a drowning and shortening of the Huron and the formation of a third delta in the northeastern part of the city of Ann Arbor. These deltas all represent important sources of sand and gravel for the cities of Ann Arbor and Ypsilanti.

When the glacial lake waters had receded to the levels of Lake Arkona, the Huron, for the first time, entered Wayne County.

8. Geological Atlas of the United States, Ann Arbor folio, No. 155, 1908, p. 10, Fig. 6.

with its mouth just east of Rawsonville and formed there the extensive delta described previously in this report. Then came again a slight shortening and drowning when the waters rose to the Whittlesey level and the formation of an extensive delta in the estuary carved by the Huron during the Arkona stages. This delta constitutes the terrace upon which the main part of the city of Ypsilanti is now built (elevation 730 to 740 feet) and may be traced along the valley as far as the Whittlesey beach, about half way between Ypsilanti and Rawsonville, where was located the real mouth of the Huron at this stage. This same peculiar history was repeated a third time, in this game of give-and-take between river and lake, as the water level dropped to that of Lake Wayne, extending the Huron as far as the southeastern corner of Van Buren township, then crowding it back to the site of Belleville and there forming the terrace described. During the early stage of Lake Lundy, the Huron mouth was at New Boston and at about the middle of Huron township during the late (Elkton) stage. It had advanced southeastward upon the fall of Lake Lundy, stood near Flat Rock during the early stage of Lake Rouge, the contemporary of Lake Algonquin, and near Rockwood during the later stage, or the correlative of Lakes Nipissing.

From this history, it is seen that the mouth end of the Huron is the youngest by many thousands of years, the meander loops from Belleville down becoming perceptably less mature. The evidence of lateral cutting by the stream, indicated by the breadth of the valley, shows less age for the lower portion. No deltas were formed at all comparable with those of the Maumee, Arkona, Whittlesey and Warren stages of the glacial lake series, although the river had grown longer and increased its drainage area. It is in its tributaries, however, that the relative youthfulness of the lower Huron is most apparent, especially when they are contrasted with those of the Rouge branches. These are short, very simply branched or not at all, and are largely *intermittent*, showing that they have only very partially cut their beds to the level of ground water. Near where they join the main stream, deep V-shaped gullies occur, but of the type known as *youthful* and requiring only a short time for their development. The main tributary of the Huron in Wayne County is Smith Creek, with its still longer tributary Silver Creek, draining northeastern Huron and southern Brownstown townships. This takes its origin within a half mile of the Huron, flows parallel with it but at a higher level for nearly eight miles and always less than a mile distant, reaching the Huron only when within a half mile of Lake Erie. Measured in terms of river his-

tory, only a short time would be required to develop lateral gullies from the Huron which would tap the bed of Smith Creek and divert the upper course more directly to the main stream. In the section of the river between Belleville and Rawsonville, there is considerably more evidence of age shown by the tributaries. Just north of the latter place (NW. ¼ sec. 19, Van Buren) Bowman has described an interesting case of stream capture,[9] in which the Huron widened its valley and cut into the bed of Oak Run, a tributary of Willow Run, which is in turn a tributary of the Huron. In this way several hundred yards of the head waters of Oak Run were diverted directly to the Huron and the Run, shortened by this amount, "beheaded". About one-half mile east, the Huron started to remove the divide between its valley and that of Willow Run, as noted by Jefferson, by which the Run would have been shortened nearly a mile. A pronounced notch was cut but before the capture was completed the Huron began to swing in the opposite direction and the work is temporarily abandoned so far as the Huron is concerned.

The same peculiarity of youthful drainage described above is shown still more strikingly by Swan Creek, which drains nearly the whole of Sumpter and the southwestern portion of Huron townships. The northern branch starts two miles north of Willis, in Augusta township, Washtenaw County, and pursues a southeasterly course parallel with the Huron and at a considerably higher level for about 23 miles to Lake Erie. Throughout the greater part of its course, it is distant from the Huron but two to four miles and at one place (one mile west of Willow) the divide is less than a quarter mile in width. The development of a short gully, tributary to the Huron at this critical point, with the assistance of a flood, or ice jam in Swan Creek would shift the upper drainage of the latter to the former and another tragedy in stream life would be enacted. This creek came into existence with the fall of Lake Whittlesey and had a history practically identical with that given for the Huron from that stage of lake development.

An entire series of streams of this same type is found along the eastern margin of the county, all of them originating subsequent to the fall of early Lake Lundy; short, straight, with very few simple tributaries and in their upper courses largely intermittent. The fall is slight, the amount of lateral and vertical cutting small in amount, with low banks, expanded, estuary-like mouths (from the *drowning*), surrounded by marsh and at ordinary stages of

9. A Typical Case of Stream Capture in Michigan: Journal of Geology, vol. xii, 1904, p 326.

the water with but slight current. Starting northward from the Huron, we first encounter Brownstown Creek, which with its tributaries drains the northern part of Brownstown and Huron, Monguagon, and the southern portions of Romulus, Taylor and Ecorse townships. The upper portions of several of the tributaries have been converted into drains and their courses thus brought under control and straightened. The natural course of these streams is southeastward, direct to the river, but the Grosse Isle moraine deflects them to the southward, many of them taking the old distributary channels, uniting them into a single system and bringing about an appearance of age not in harmony with their real state of development. Monguagon Creek, lies chiefly in the northeastern corner of Monguagon township, east of the Grosse Isle moraine, consisting mainly of an intermittent and a drowned portion (Pl. XIX, A), the latter in size entirely out of proportion with the former. Frenchman's Creek, upon Grosse Isle, is another similar stream lying in a distributary at the southwestern corner of the island.

Ecorse River furnishes another case similar to that of Brownstown Creek, in that two of the three branches are deflected, one to the north, the other to the south, by the beach deposits of the Second Rouge beach. The middle branch is short and aborted, its upper drainage basin having been invaded by the tributaries of the other two branches and its natural supply of water thus reduced. The three branches drain central Ecorse, northern Taylor, northeastern Romulus, southeastern Nankin and southern Dearborn townships. From the mouth of the trunk stream, the drowned condition extends for a distance of nearly two miles up the three branches, evidenced by low banks, broad channel, sluggish current and abnormal depth (Pl. XIX, B). Just opposite the mouth in Detroit River, the lake chart shows a depth of 27 feet. Savoy Creek, obliterated by grading and sewers, formerly crossed the central portion of the city of Detroit, near the river front, flowing southwestward in the depression just north of Jefferson Avenue and emptying into the river near the present site of the Michigan central portion of the city of Detroit, near the river front, flowing of the city was formerly drained by Bloody Run, much of which has also been diverted and obscured, but with a little changed portion in Elmwood Cemetery and vicinity. The region east of the Detroit moraine, northeastern corner of Wayne County, is drained by Connors Creek, Fox Creek and Milk River. The largest of the three is Connors, which starts in the southern part of Warren township, Macomb County; flows southeastward, draining

northeastern Greenfield, Hamtramck and western Gratiot townships, reaching the river about one mile east of the Detroit Waterworks. The fall in the stream within the county is 45 feet, or at an average rate of six feet to the mile, giving banks in the middle course 12 to 18 feet high. The natural tributaries are few, short and simple but numerous drains utilize the creek as an outlet. Passing through Mt. Olivet Cemetery and through a thickly populated district of heavily manured truck farms this stream has been a menace to the city of Detroit, since it empties its waters above the intake pipe of the city system. Fox Creek is a much smaller stream draining the eastern part of Gratiot and the western parts of Grosse Point townships. The Emmet moraine has given this stream a southwesterly direction for all except the last mile of its course, where it has broken through and empties into the river at Windmill Point. Much of the creek has been ditched and it receives also the flow from numerous artificial drains in this depressed area. The stream is almost completely enclosed by the 580-foot contour (Detroit River being but 575 feet here) so that it has but little fall. A very insignificant creek is "Milk River", draining the extreme northern portion of Grosse Point township to the northeastward behind the Emmet moraine. It is all intermittent except for the last mile of its course, which is drowned.

Unless one has carefully followed the course of events narrated in the preceding pages, it will come as a surprise to the reader to learn that Detroit River, one of the most magnificent in the country, as well as most commercially important, should be amongst the youngest in the Wayne County series. Gazing upon its great expanse of blue, sweeping rapidly by, with its constant procession of vessels laden with freight and passengers, and then glancing at the relatively insignificant tributaries that enter it from the west, such discrepancy in age seems almost unbelievable. Detroit River, however, more of the nature of a *strait* (which the name means in French) than at present, did not make its appearance until Lake Rouge, the correlative of lakes Algonquin and Nippissing had been formed. Streams as small and young as Brownstown, Campbell and Connors Creek had already made their start in their upper courses. The course of the Detroit appears to have been determined in large part by the series of depressions formed across the back of the Detroit moraine by the ice front at the time of the formation of the Emmet and Grosse Isle moraines. Although submerged at the time, and long subsequently, when the level of the water fell sufficiently, the dominant depression, or depressions, determined the direction of flow. During the life

of Lake Algonquin, when the discharge was entirely by the Kirkfield, or Chicago outlet, and while Lakes Nippissing were draining through the Mattawa-Ottawa channel, the discharge from the upper lakes was temporarily withdrawn, the Lake Erie level was reduced and the Detroit carried only the limited drainage collected southward from Port Huron. It was during these stages that the tributary streams cut their channels to such a depth below the present level of the river.

Measured along the channel, the river has a length of 28 miles, opposite the city of Detroit a breadth of 2200 feet, broadening to 4 miles at the mouth. The greatest depth observed is 45 feet opposite Woodward Avenue and ranges from 25 to 40 feet along the main channels.[10] The least depth and, indeed, the *sill* of the Great Lakes is at the Lime Kiln Crossing where the ordinary depth is 18 feet and this depth has been secured and maintained only by dredging. Where the Grosse Isle moraine crosses the river, as in the vicinity of Trenton and Detroit, the river contains numerous islands, the largest of which are Grosse Isle and Belle Isle. These islands, as well as a number of the others, carry morainic ridges, roughly parallel with those upon the mainland, and seem to represent fragments of the moraines, the backs of which are above the present water plane. From the head of Fighting Island to Belle Isle, a distance of over 9 miles, the river lies to the west of the moraine, has cut a deep channel in the soft deposits and contains no islands. The surface elevation of the river and its current varies with the level of Lake St. Clair, from which it starts and that of Lake Erie into which it empties. These levels are subject to much variation owing to the season, special climatic conditions, the force, direction and duration of the wind, etc. The ordinary level of Lake St. Clair is given as 576.17 feet above sea level and that of Erie as 573.11 feet, giving a fall of 3.06 feet for the river surface, or an average of about .11 foot to the mile. Opposite Detroit, the average surface velocity is about two miles an hour as determined by Clarence W. Hubbell, Engineer for the Detroit Water Board. In the preliminary work for the Detroit River tunnel, numerous determinations were made opposite 10th street, at varying depths. The greatest velocity observed was 2.32 miles per hour (3.40 feet per second) at a depth of 15 feet and nearly three quarters of the distance across the river from the Detroit side (see Pl. XII). The maximum surface velocity was just over

10. Through the work of the corps of engineers, U. S. Army, a careful survey has been made of the river and is the subject of continuous study and observation. Their charts of the river may be obtained from the Detroit office, Moffat Building, Griswold street.

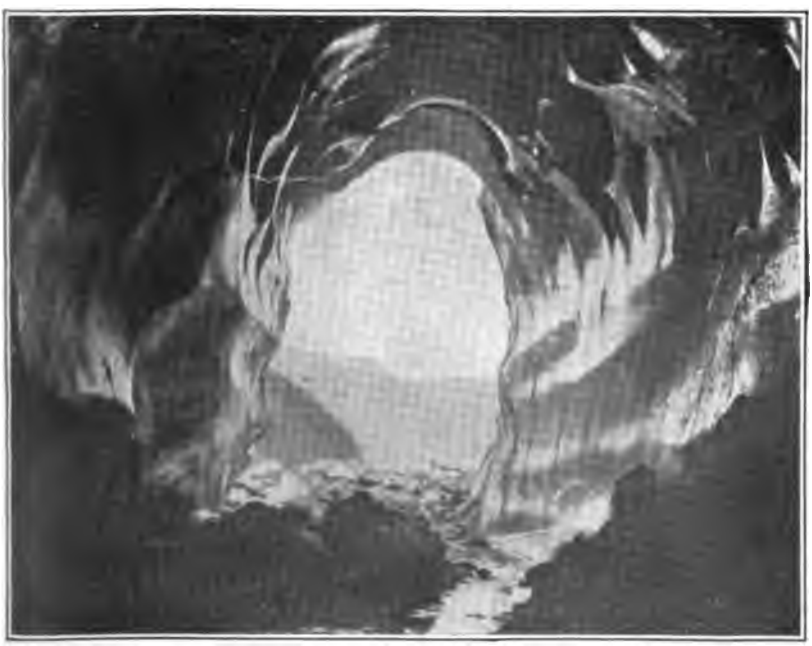
this point and was found to be 2.18 miles per hour, or 3.20 feet per second, diminishing to 1.91 feet per second towards the Detroit side. Near the bottom, the maximum velocity noted was 1.56 miles per hour (2.29 feet per second) and the minimum .80 miles per hour, or 1.17 feet per second, at places beneath the points of maximum and minimum surface velocity respectively.

Although the main channel followed by the lake shipping lies upon the Canadian side of the river, between Bois Blanc Island and the mainland, the work of keeping this section of the river open has devolved entirely upon the U. S. Government. With a heavy blow from the west of any considerable duration, the water of Lake Erie is lowered about the mouth of the river and the depth of water in the neighborhood of Ballard's Reef and the Lime Kiln Crossing is so reduced that heavily laden boats are often detained. To obviate this difficulty as well as provide an American channel, the so-called Livingstone Channel[11] has just been constructed for the general government, by the contractors Grant Smith and Company and Locker. This channel consists of four sections, stretching from Ballard's Reef, just north of Stony Island, to deep water in Lake Erie, or a distance of about 11.9 miles. The material removed has consisted of dolomitic bedrock, boulders, till, silt, sand and gravel. From the geological standpoint the most interesting section of the channel is that opposite Stony Island, where about 150 acres of the river bed were laid bare by means of a coffer-dam (Pl. XX, B) and a 20-foot cut, 5750 feet long by 450 feet broad, made into the Monroe dolomites which overlie the Sylvania sandstone. Work was begun April 14, 1908, upon the dam, approximately 1,500,000 cubic yards of rock being removed, and has now been filled and put into commission. To bare the rock, it was estimated that 400,000,000 gallons must be removed and this was accomplished in 10 days by driving the water through 8 inch tubes by means of compressed air (see Pl. XXI, A).

Lakes, ponds, swamps and drains. With the neighboring counties of Washtenaw and Oakland so exceptionally well supplied with lakes, it seems rather strange that Wayne should have almost none whatever, except St. Clair and Erie upon her eastern border. Aside from the ox-bow lakes, or "bayous," along the Huron and Rouge valleys there is but one natural body of water in the county that can be called a lake (Pl. XXVI). This lake is small, only about 840 by 1170 feet, elliptical in outline and situated about

11. Named in honor of William Livingstone, president of the Lake Carriers' Association.

A. SURFACE STREAM VICTORIA GLACIER, CANADIAN ROCKIES.

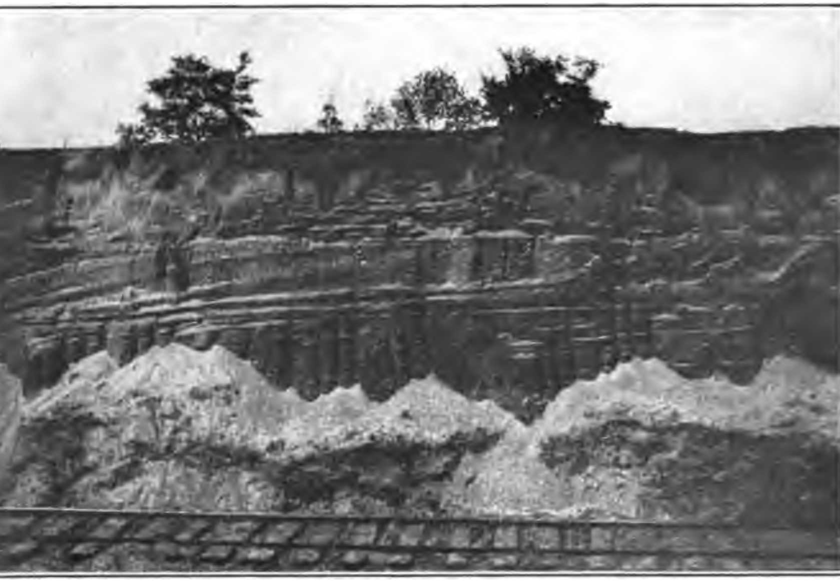


B. MOUTH OF SUBGLACIAL TUNNEL, VICTORIA GLACIER.
(PLATE XIII A & B COURTESY SMITHSONIAN INSTITUTION.)

ANCIENT DRAINAGE CHANNEL, DEFIANCE STAGE OF ICE. LOOKING SOUTHEASTWARD FROM WESTERN BANK.

A. DISTANT VIEW OF WHITTLESEY BEACH, UTILIZED AS DWELLING SITE. LOOKING SHOREWARD FROM FORMER LAKE BED.

B. SECTION OF DELTA GRAVELS, LAKE WHITTLESEY STAGE. PERE MARQUETTE GRAVEL PIT, NEAR PLYMOUTH.



SECTION OF DELTA GRAVELS, LAKE WHITTLESEY STAGE. PERE MARQUETTE GRAVEL PIT, NEAR PLYMOUTH.

B. CUT BEACH, SECOND ST. CLAIR STAGE, MILK RIVER POINT.

A. DELTA GRAVELS, FIRST STAGE OF LAKE ROUGE.

B. "THOROUGHFARE", GROSSE ISLE, A DISTRIBUTARY CHANNEL.

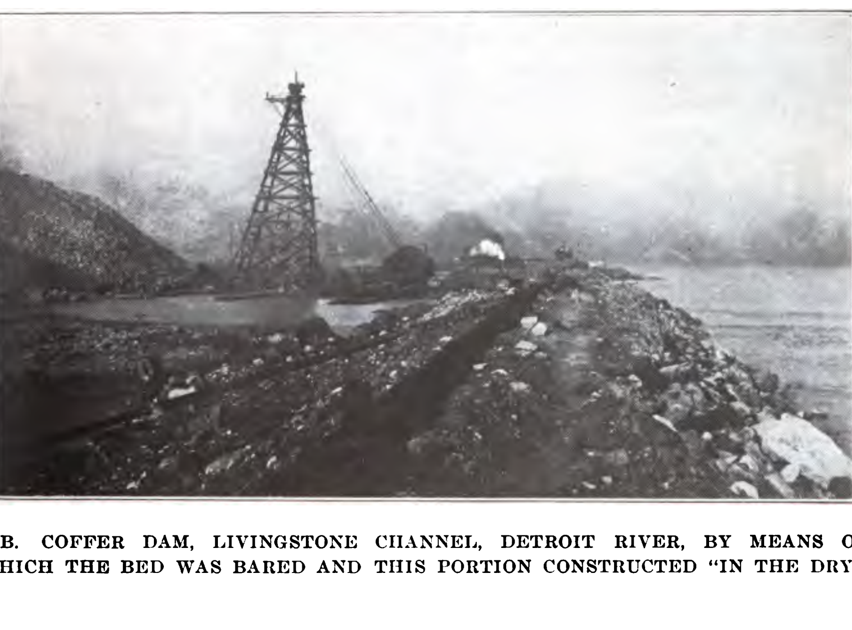
A. SYSTEM OF VERY YOUNG CONSEQUENT STREAMS OVER WIND BLOWN SAND DEPOSIT.

B. LOWER ROUGE AT FLOOD, WAYNE.

A. HURON RIVER AND TERRACE AT FRENCH LANDING.

B. COFFER DAM, LIVINGSTONE CHANNEL, DETROIT RIVER, BY MEANS OF
HICH THE BED WAS BARED AND THIS PORTION CONSTRUCTED "IN THE DRY."

A. HURON RIVER AND TERRACE AT FRENCH LANDING.



B. COFFER DAM, LIVINGSTONE CHANNEL, DETROIT RIVER, BY MEANS OF
HICH THE BED WAS BARED AND THIS PORTION CONSTRUCTED "IN THE DRY."

one mile east of the village of Northville (SW. ¼ NE. ¼ sec. 2). The average depth of the lake is given by the present owner (Mr. S. W. Curtiss) as 28 feet, with a maximum of 39 feet, and is fed by springs. It is surrounded by some swamp and drains southwestward into the Middle Rouge at higher levels, but is now without outlet. It was considered as a source of water supply for the village of Northville but is not high enough (somewhat under 800 feet) to give the necessary gravity pressure. It is well stocked with fish; bass, pike, perch, blue gills, and "bull heads".

Where the streams are dammed for milling purposes, artificial ponds occur as expansions of these streams, as at Northville, near Plymouth, at Pikes Peak on the Middle Rouge and at Belleville, New Boston and Flat Rock on the Huron. The dam serves to broaden and deepen the stream, checking the current and giving rise to marshy conditions about the margin. The largest of these ponds is found at Belleville. More or less standing water occurs in the clay pits at Dearborn, West Detroit and Leesville, seeping in through the clay, or collecting from rainfall and drainage, and in the abandoned quarries on Grosse Isle, Stony Island and near Gibraltar. Small ponds, fed by springs, supply the village of Plymouth and the U. S. Fish Hatchery at Northville (Pl. XXVIII, B).

Owing to the generally flat topography and the presence of moraines and beach deposits, portions of Wayne County are but poorly drained and there are still some extensive marshes. Along the margin of Detroit River, about the islands and about the Erie shore there are patches of marsh, the most extensive of which is found in southeastern Brownstown and between the Ecorse and Rouge. The drowned condition of the mouths of the streams and the flooding of the distributaries is responsible for the landward extension of these swamps, sometimes to a distance of two to three miles. Before being brought under cultivation as thoroughly as at present, these patches were much more extensive, being reduced, or entirely obliterated by artificial drainage, clearing of the forests and the cultivation of the soil. It was these marshes that rendered travel so slow and laborious in the early days, led to the selection of the beach ridges for roads and trails, furnished breeding places for the mosquito, which, in turn, gave rise to malaria and helped to establish the thoroughly bad name that the state possessed in an early day as a place of residence. The Higgins' map of the county shows the location of these originally poorly drained areas. A "tamarack marsh" is indicated in north-

eastern Redford and northwestern Greenfield covering about four square miles. Most of this has disappeared, although some still remains in secs. 4 and 5 of Greenfield, directly upon the crest of the Detroit moraine. "Open marsh" is also indicated for secs. 9, 10 and 15, which has been practically gotten rid of by a system of drains eastward into Connors Creek and southward into Campbell Creek. A marsh in sec. 10, Redford, has been similarly drained. Portions of secs. 1 and 12 in northeastern Greenfield and adjacent secs. 5, 6, 7, northwestern Hamtramck; also portions of secs. 3. 16 and 17 show swamp, being hemmed in between the Detroit and Grosse Isle moraines. This is the portion of the county in which artificial drainage has been most extensively practiced and with results that have fully justified the expense. A long strip of marsh extending along Fox Creek in the western part of Grosse Point was labeled "wet prairie and marsh". Secs. 17, 18, 19 and 20 of Nankin contained a patch of marsh originally which has not yet been entirely drained, although considerably reduced in size. The middle sections of Canton township, and portions of secs. 9. 19, 31 and 32 of Van Buren were found by Higgins to be wet. In the latter township, this condition still exists to a greater or less extent in secs. 7, 8, 17, 18, 19, 20, 29 and 30. "Big Bear swamp" was located in the northeastern corner of Van Buren (secs. 1 and 12) and the northwestern corner of Romulus townships (secs. 6 and 7), now drained into tributaries of the Lower Rouge. Eastern Romulus and Taylor (formerly Ecorse) are marked "wet prairie". also the southern half of Sumpter, the northeastern corner of Huron and the northwestern corner of Brownstown townships. In secs. 5, 8 and 9, of northern Brownstown, some 400 acres of undrained swamp still remain, drainage being somewhat difficult in this region owing to the flat topography and the Grosse Isle moraine to the east. The drainage here, as well as to the north and south, is into Brownstown Creek. The marshes along the river and lake front were, and still are, utilized by the French inhabitants as hunting grounds for wild fowl and muskrats. The highest marsh in the county (about 840 feet above sea level) is located in the old drainage channel (see Pl. X) that crosses the northwestern corner, where it is hemmed in by moraine and lies on the divide along this channel in secs. 19 and 30 of Plymouth township.

SOILS AND SUBSOILS.

General characteristics. The soils and subsoils of the county of Wayne may be simply classified under five heads; four of them

being derived either directly or indirectly from the glacial deposit known as till. This material was produced by the grinding action of the great ice sheets upon the surface layers of bedrock to the northeastward and with it were mixed more or less preglacial soil, wind and water borne material. The soils, then, with which we are concerned in this report are referred genetically to those of the *transported* class; as distinguished from the so-called sedentary, or residual soils, which are formed *in situ* from bedrock.[12] Of the varieties to be briefly described below, the differences are due in large part to the texture, or degree of fineness, of the constituent granules and to a somewhat less extent to the actual mineral composition. No sharp lines can be drawn between the different varieties, one often shading into the other by imperceptible gradations.

By *soil* is usually meant the eight to twelve inches of the loose, finely divided debris that mantles the bedrock; that which is within reach of the ordinary processes of cultivation. Beneath this lies the *subsoil*, not sharply separated from the soil layer and extending from it to the bedrock, often many feet down. Owing to the action of plant roots, burrowing life forms and frost, the soil is loose and porous. When compared with the subsoil, it is often darker from the presence of organic matter or, when this is lacking, more highly colored from the rusting of the iron ingredient. In this climate, for reasons not yet fully comprehended, the subsoil shows less fertility when first brought under cultivation, as shown in the "dead-furrow", produced in plowing by throwing the soil in opposite directions and thus exposing the subsoil. In arid regions, it is said that no such difference in fertility exists.[13] Iron and calcium carbonate are not infrequently dissolved from the soil by percolating water, especially when charged with carbon-dioxide gas, and deposited in the subsoil, sometimes as a crust, more often as a filmy deposit in the interstices of the subsoil. As a result, there is sometimes seen in the section of a bank a more deeply rusted streak of iron stain than exists in the soil itself. When tested with the dilute acid the soil often shows slight reaction (due to leaching of the carbonates), the subsoil immediately beneath vigorous effervescence (due to secondary enrichment) and the deeper layers of subsoil moderate effervescence, due to the carbonates originally present.

Clay soils. The clay soils of Wayne County fall naturally under

12. A discussion of the soils that originate thus from the bedrock found in southeastern Michigan will be found in the writer's report upon Monroe County: Geological Survey of Michigan, vol. VII, part I, 1900, p. 149.

13. King, Physics of Agriculture, 1907, p. 50.

two heads, those derived directly from the till by long exposure to the soil making agencies and those which have been extracted from the till by water held in suspension, transported and redeposited under quiet conditions. The former we may characterize as the glacial clay, the latter as the lake, or river clays. They are alike in that they consist of a great variety of very finely divided mineral particles, under the microscope appearing quite fresh and angular in outline. Owing to this fine texture they are readily converted into good soil and, owing to the variety of minerals represented, they furnish an abundance of plant food suitable for the heavy cereals. Their fine texture greatly enhances their value for agricultural purposes since this fineness increases the total granular surface available for the retention of moisture. A cubic foot of solid rock, such as granite, has 864 square inches of surface, but if sawed into eight equal cubes, six inches upon a side, it now possesses 1728 square inches of surface. If cut into one inch cubes the total surface would be increased to 10,368 square inches (1728 x 6), or twelve times as great as the original surface of the cube. If this subdivision continues until we have to each single gram of soil many million individual particles, the combined surface of these is enormously increased.[14] When too finely divided, however, the soil becomes so damp that it is "cold" and the passage of air through it, necessary for the proper aeration of roots, is prevented. The clays are alike in being sticky and plastic when wet, in that they harden, shrink and crack upon drying and that they possess enough iron to burn red. The glacial clays are very compact, unstratified, generally more or less pebbly, with occasional coarse boulders, either resting upon the surface or embedded. The deeper layers are generally of a bluish color, the upper few feet being rusted to a drab, brown, yellow or red. The uppermost 6 to 12 inches are darker in color, looser in texture and more or less leached of their readily soluble ingredients. Produced as they were, it is obvious that they may differ greatly in composition within short distances, consisting essentially of varying quantities of silica and alumina, with carbonates, iron oxide, etc. The soils of Wayne County have not yet been subjected to analytical study by any interested bureau but those essentially similar, lying just north in Oakland County, have been so studied by the U. S. Department of Agriculture and reported upon in a

14. King has shown that with granules all the same size and of spherical form the number in a single gram of soil would be astonishingly great; for instance with a diameter of .01 mm. the number would equal 720,000,000 and for .0001 mm. would equal 720,000,000,000,000 (Physics of Agriculture, p. 117). In the latter case the combined surface of these granules would be equal to 226,415 square centimeters, or approximately 244 square feet.

bulletin procurable from Washington.[15] The glacial clays here described are referred to as "Miami clay loam" and three typical soil samples, with the corresponding samples of subsoil, from depths of 10 to 36 inches, were subjected to mechanical analysis, with the results given below. In these and the following analyses taken from the report varying proportions of organic matter, fine gravel, sand, silt and clay are indicated, throwing light upon the physical characteristics of the respective samples and furnishing inferences relative to chemical composition. The method of analysis consists in first passing the sample to be employed through a two millimeter sieve, so that in the tables given nothing coarser appears and no data are furnished as to the amount of such material thus removed. For detailed description of the method employed see "The Centrifugal Method of Mechanical Soil Analysis", Bulletin No. 24, 1904, U. S. Department of Agriculture.

15. Soil survey of the Pontiac Area, Michigan, 1904.

TABLE XI.—MECHANICAL ANALYSES OF GLACIAL CLAY, OAKLAND COUNTY.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 mm. to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
9596	Sec. 5, Troy tp.	Clay loam, 0 to 12 inches	2.21	1.16	4.06	5.70	17.24	12.20	40.22	19.42
9597	Subsoil of 9596	Clay loam, 12 to 36 inches	.10	.70	2.60	3.60	12.74	15.20	34.36	30.68
9598	Sec. 17, Pontiac tp.	Heavy loam, 0 to 10 inches	.75	1.98	4.76	5.48	19.06	16.34	28.38	23.88
9599	Subsoil of 9598	Clay loam, 10 to 36 inches	Tr.	1.04	3.20	4.04	13.68	14.18	32.40	31.06
9600	Sec. 30, Farmington tp.	Heavy clay loam, 0 to 8 inches	1.80	.78	3.96	5.06	14.80	12.36	34.22	28.78
9601	Subsoil of 9600	Stiff clay loam, 8 to 36 inches	.34	1.04	2.16	2.36	8.10	9.50	31.02	45.72

No. 9599 contained 10.58 per cent of calcium carbonate and No. 9601 contained 6.96 per cent.

TABLE XII.—MECHANICAL ANALYSES OF LAKE CLAY SOIL AND SUBSOIL, OAKLAND COUNTY.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
9604	Sec. 26, Troy tp.	Black clay loam, 0 to 10 inches	3.50	1.46	3.54	4.62	10.34	15.20	33.74	25.04
9605	Subsoil of 9604	Drab clay loam, 10 to 36 inches	1.45	.50	2.76	3.52	12.74	16.70	34.74	28.90

From this table, it is seen that the bulk of the material of each sample consisted of what is listed as silt and clay, with a considerable quantity of fine sand. This type of soil is difficult to work, when too dry; being stiff and hard and, when too wet, forming clods which are exceedingly difficult to reduce. It can be worked to advantage between certain moisture conditions only and very much needs thorough drainage. The original forest growth was black walnut, hickory, maple, beech, ash and several species of oak. By proper culture, good crops of wheat, oats, rye, corn and hay may be grown upon these soils. The Department of Agriculture suggests dairying wherever there exists a good market for dairy products; otherwise stock raising. In Wayne County, these soils cover the morainic knolls and ridges in the northwestern corner and eastern portions of the county and are found on the till plain between, where it has not been covered with lake clay, sand or gravel.

The lake clays are much more limited in extent, having been deposited mainly in the vicinity of Detroit as described previously. Their average texture is finer and much more uniform than that of the glacial clays; pebbles and boulders are very rare. They are often very regularly and delicately laminated, the laminae being separated by a very thin layer of minute sand particles. Owing to this structure these clays are much more permeable to water and surface changes, similar to those already described, may readily occur. Originally deposited in depressions they were naturally poorly drained, furnished favorable conditions for the growth of certain plants and are dark at the surface from the presence of this decaying organic matter. A series of chemical analyses of these subsoils has already been given in table IX of this report. What appears to be the same type of soil, judging from its occurrence, is referred to in the Pontiac bulletin (page 19) as the "Miami black clay loam" and the following mechanical analysis given. The small amount of very fine gravel may be due to overwash from adjacent higher land.

When wet, these clays are excessively sticky and were responsible for the wretched roads leading out from Detroit; those to the westward being practically impassable for teams at certain seasons. This fact has necessitated heavy county expenditures for macadamized and concrete roads. Naturally low and requiring drainage these deposits have also forced the owners to provide extensive systems of drains in order to carry on their agriculture with any degree of success. Owing to the slight fall procurable in these drains they are often expensive to keep open and a source of annoy-

ance. In the early spring considerable areas are often flooded from the heavy rains and melting snows, causing damage to the wheat and delaying the spring tillage. When properly drained, wheat, corn, oats and hay furnish a good yield. In Oakland County, this soil is preferred for sugar beets giving an average yield of 10 to 12 tons to the acre. In the vicinity of Detroit the soil is extensively and very successfully utilized in truck farming. The original timber upon this land was largely elm, soft maple, basswood, and black ash, with some beech, oak, hard maple and whitewood on the higher and better drained portions.

Sand and gravel soils. Although typical sand and gravel soils are essentially different in appearance and agricultural importance, they may merge into one another at the limits and have had a similar origin and history. Their derivation from the till by stream, or wave action, has been described on previous pages. In the bed of the old glacial drainage channel, both sand and gravel were removed from the till while it was still covered with the ice and deposited between the two morainic ridges (Ft. Wayne and Northville) which diagonally cross northwestern Northville and Plymouth townships. Subsequently, during the lake stages the streams were active during flood, cutting both vertically and horizontally into the glacial clay, taking the finer materials into suspension, rolling along the bottom some of the coarser and depositing them in such a manner as to secure imperfect assortment. The deltas and delta terraces received alternating deposits of sand and gravel, as the currents fluctuated, while the finer silt and clay particles that reached the lakes remained in suspension longer and settled in the more quiet waters. Along the shore line, during times of maximum wave action, a similar mechanical separation of the till deposits occurred, the sand and gravel being thrown up to form a beach, while the finer sediment slowly worked its way lakeward. Upon drying, the sand was here and there gathered by the winds into knolls and ridges (dunes), or spread as a surface dressing over the clay. These strips, representing the approximate shore lines, have been previously located and will be again given in the summary by townships (Chapter IX).

The pebbles are sub-angular to rounded in form and of great variety of composition, having been derived from the glacial till. From one-third to one-half of them are dolomites and limestones and about one-fifth are crystallines and the same proportion are quartzites. The sand grains under the microscope show the effects of abrasion and appear somewhat rounded, but only to a light extent when compared with those subjected to long continued cur-

A. BARED MONROE STRATA, BED DETROIT RIVER, SHOWING DISSOLVING ACTION OF WATER UPON DOLOMITIC LAYERS.

B. AN EXHAUSTED FARM, READY FOR REFORESTATION.

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rent, or wave action. The material represented is very largely quartz; the softer, decomposable and cleavable minerals having largely disappeared. This means that the sandy soils possess relatively little available plant food, a relatively small granular surface and consequent inability to retain moisture. They have the advantage of being light, easily tilled and readily drained. When ordinary crops are grown upon them the returns are generally meager and what little fertility was originally present is soon exhausted (see Pl. XXI, B). These soils are best adapted to rye, beans, potatoes, truck crops and small fruits. With intensive methods of farming and careful management good crops of corn, rye and hay may be grown upon soil once exhausted. The natural forest growth was scrub oak, with some chestnut and butternut. In the Pontiac area, these sands were classified as "Miami sand" and three mechanical analyses given, with those of the corresponding subsoils.

TABLE XIII.—MECHANICAL ANALYSES OF SANDY SOILS OF LAKE ORIGIN, OAKLAND COUNTY.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.001 mm.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
9614	Cen. Sec. 36, Farmington tp.	Fine sand, 0 to 8 inches	2.21	1.62	5.86	13.30	44.46	20.30	7.96	6.12
9615	Subsoil of 9614	Fine sand, 8 to 36 inches	.50	.26	.98	2.90	46.82	40.66	5.22	3.00
9616	NE. cor. Sec. 22, Royal Oak tp.	Medium sand, 0 to 10 inches	1.63	3.10	18.10	29.24	28.24	5.30	9.72	6.30
9617	Subsoil of 9616	Sand, 10 to 36 inches	.53	3.54	19.46	32.42	27.66	5.02	7.04	4.84
9618	Sec. 10, Waterford tp.	Sand, 0 to 8 inches	.64	.96	8.30	23.50	48.80	6.70	7.32	4.20
9619	Subsoil of 9618	Sand, 8 to 36 inches	.16	1.40	8.16	19.42	53.48	7.52	6.36	3.24

Loam. This term is applied to an admixture of sand and clay, which partakes of the nature of both to an extent, combining their good characteristics, agriculturally speaking, and eliminating those of an objectionable nature. It has resulted from the mechanical mixing of the two chief ingredients along the strip, sometimes of considerable breadth, separating the belts of sand from the areas of clay. This result may have been secured in a variety of ways; as when the lake sands and lake clays were being simultaneously deposited; by having a thin layer of sand spread over one of clay, or vice versa, as a lake deposit; the same result was secured by overwash from higher land, or by wind borne sand or dust. The work of earthworms, ants, crayfish, along with larger burrowing forms, root action, frost, etc., has, in the course of time, combined the two ingredents into a single type of soil. This is not so sticky when wet as the clay, does not harden and crack upon drying and hence can be worked with greater ease. It is sufficiently open and porous to permit of aeration and drainage and at the same time contains sufficient fine material to supply plant food and moisture. It is often dark colored from the presence of partially decayed organic matter; which serves a double purpose in supplying first, plant food and second, in enabling the soil to absorb so much additional heat because of this color.

When the clay ingredient predominates, the soil is referred to as a clay loam and when the sand is plainly in evidence, as a sandy loam, which may, with the introduction of pebbles, pass into a gravelly loam. No line of demarcation can be drawn between these different varieties, nor between loam and clay, or loam and sand. The most valuable lands in the county, from a purely agricultural standpoint, are these loams and they are adapted to the growing of all crops that may be raised upon either the clay or sand separately. When well drained, they produced also the greatest variety of natural forest growth.

A type of clay loam, in which the body of the soil is a glacial clay, has been mapped and described in the Pontiac area as "Oakland sandy loam". The same type of soil may be recognized in limited patches in Northville and Plymouth townships. The following mechanical analyses were made from the Oakland County samples.

TABLE XIV.—MECHANICAL ANALYSES OF GLACIAL CLAY LOAM, OAKLAND COUNTY.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
9624	Sec. 27, Waterford tp.	Sandy loam, 0 to 10 inches	1.77	1.86	6.92	11.02	28.22	13.84	26.80	10.92
9625	Subsoil of 9624	Clay loam, 10 to 36 inches	.62	2.00	6.52	7.00	19.54	11.74	28.44	24.32
9626	Sec. 10, Bloomfield tp.	Sand loam, 0 to 15 inches	1.73	1.58	5.12	7.78	25.38	15.24	32.26	12.40
9627	Subsoil of 9626	Clay loam, 15 to 36 inches	.94	1.72	4.22	7.30	24.72	12.92	30.88	18.16
9628	Sec. 27, Pontiac tp.	Heavy sandy loam, 0 to 10 inches	2.54	1.06	3.96	8.16	25.02	12.62	34.42	14.74
9629	Subsoil of 9628	Clay loam, 10 to 36 inches	1.17	1.12	2.88	4.10	13.80	9.24	35.24	33.20

TABLE XV.—MECHANICAL ANALYSES OF LACUSTRINE SANDY LOAM, OAKLAND COUNTY.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
9606	Sec. 21, Avon tp.	Loamy sand, 0 to 16 inches	2.06	3.42	11.78	15.00	33.22	14.72	14.42	7.26
9607	Subsoil of 9606	Sand, 16 to 36 inches	1.69	5.22	13.82	15.92	30.08	15.28	13.04	6.56
9608	Sec. 16, Bloomfield tp.	Medium sandy loam, 0 to 12 inches	1.10	1.88	7.44	11.26	25.06	20.36	25.16	8.60
9609	Subsoil of 9608	Medium sand, 12 to 36 inches	.20	2.20	8.62	11.60	25.80	20.94	22.64	8.20
9610	N. Sec. 22, Southfield tp.	Sandy loam, 0 to 10 inches	.79	2.16	8.04	15.86	37.80	14.70	13.08	8.34
9611	Subsoil of 9610	Sand, 10 to 36 inches	.71	1.40	6.36	14.28	42.12	16.30	12.28	6.70

A somewhat different variety of loam, formed along the margins of the glacial lakes Maumee, Whittlesey and Arkona, was described in the Pontiac survey as "Miami sandy loam" and the following mechanical analyses given (table XV). The typical areas figured from which the samples were selected are simply an extension of the soil belt found in Livonia township.

Silt. Another type of soil closely related to the preceding, but of more limited extent, it is convenient to recognize under the head of silt. It is confined mainly to the flood plains of the streams, is more or less distinctly stratified, dark from organic matter, loose in texture and often contains shells of both land and water forms. The material is more coarsely textured than clay and less so than sand, in the mechanical analyses above given being assigned the range of .050 mm. to .005 mm. (.002 inch to .0002 inch). Hilgard gives a range of .072 mm. to .016 mm. and Merrill .01 mm. to .005 mm. for this class of material. It may readily pass into sand upon one hand and clay upon the other, which may be conveniently termed alluvial sand, or alluvial clay, respectively, while the silt itself is often referred to as alluvial loam. The composition is often rendered variable from the deposition over it of material washed from the adjacent banks. Favorable conditions for plant growth often lead to the introduction of much organic matter. So far as known, no analyses of this type of soil have been made in Wayne County, nor in the Pontiac area, but in 1893 Prof. R. C. Kedzie published the chemical analyses of two samples of soil from the River Raisin bottoms,[16] which may be assumed to be essentially like that found along the Huron and Rouge rivers, when it is considered that the materials were all derived from the same type of till deposit.

No. 1. River Rasin bottoms, Deerfield, Lenawee County.
Selected by Geo. H. Kedzie.
Forest growth: ash, basswood, hickory, black walnut, oak, etc.
Soil cultivated forty years, without manure.

Sand and silicates	58.17
Alumina	6.48
Oxide of iron	7.62
Lime	1.98
Magnesia	1.43
Potash	1.84
Soda	1.20

16. Michigan Soils: Bulletin 99, Michigan State Agricultural College, 1893, p. 6.

Sulphuric acid	.32
Phosphoric acid	.40
Organic matter containing .42 nitrogen..	10.97
Water	9.45

Capillary capacity for water, 65.60.

No. 2. River Rasin bottoms, Deerfield, Lenawee County.
Selected by Geo. H. Kedzie.
Virgin soil.
Timber: ash, basswood, black walnut, oak, etc.

Sand and silicates	62.42
Alumina	10.64
Oxide of iron	3.46
Lime	2.10
Magnesia	1.59
Potash	2.05
Soda	1.19
Sulphuric acid	.24
Phosphoric acid	.41
Organic matter containing .37 nitrogen..	9.39
Water	6.08

Capillary capacity for water, 61.20.

When properly drained and protected from floods by dykes this soil has all the advantages of loam previously noted, but owing to the danger from overflow these flats are generally allowed to grow up with grass and are used for pasturage. In the Pontiac area they are all classed and mapped as "meadow." So far as timber was originally able to get a foothold upon these areas, it consisted in the main of elm, bass, sycamore, cottonwood and willow. But in addition, there occurred black walnut, butternut, ash, oak and maple.

Muck. One characteristic of a glaciated region, especially the morainic portions of it, is the presence of undrained portions in which spring and surface water may accumulate. In connection with the beaches, where the surface cover of sand over the clay is thin, patches of poorly drained areas occur of a similar nature. With an abundance of moisture and rich soil, a variety of plants get a foothold which in time gradually fill up the depression and displace any open water present. When conditions were favorable for the growth of *Chara* for a sufficient length of time, the lime carbonate which it secretes and deposits over its stems, accumulated upon the bottom faster than it could be dissolved by the

water and a bed of white, chalky material was formed known as marl. More or less clay, sand, or gravel were often brought into the area of marl accumulation and incorporated into it, along with the shells of numerous water mollusks.[17] With the shallowing of the water thus produced other plants, of a higher order, obtained a foothold such as the rushes, sedges, cat-tails, reed-grasses, arrowheads, pond-lilies, etc. Their remains, immersed in water and thus allowed to but partially decay, often completed the process of filling up the pond, or lakelet, and the shallow, swamp plant societies gave way to the bog and wet meadow varieties, such as *Carex* and *Sphagnum,* varieties of sedges and moss respectively. These forms, dying beneath and growing above were often able to raise the surface of the bog several feet above the original water level and thus contribute additional organic matter to that already deposited in the swamp. The researches of Davis have shown that floating mats of *Carex* and other plants may extend lakeward from the shore, over deep water, and partially decaying assist in the formation of deposits many feet in thickness.[18] Such partially decayed organic matter, however formed, slightly compacted from pressure gave rise to *peat*. When freshly cut it contains 60 to 90% of water and upon drying shrinks to two-thirds, or one-half, its original bulk. If now examined, it is found to be light in weight, light brown to black in color, porous to compact in structure and it absorbs water readily. The composition and uses of peat will be treated in another connection under the head of economic products (Chapter VIII).

Considering the method of its formation it is evident that the organic matter composing the peat is very liable to have mixed with it more or less marl, sand, silt and clay. These materials may have been introduced at the time the peat was in process of formation, as the result of stream, wave or wind action, or may have been derived from the decay of plant and animal forms. They may have been introduced subsequently by stream or wind action or by the various plant and animal agencies whereby soils and subsoils may become mechanically mixed. The result would be the formation of a type of soil known as *muck* and characterized by its deep black color, high content of organic matter, loose texture and light weight. Different varieties may be recognized depending upon the nature and amount of the material combined with the original organic matter. None of the mucks can be utilized for

17. For further discussion of marl turn to later page of this report.
18. Ann Arbor Folio, No. 155, 1908, page 8.
Report of the State Board of Geological Survey of Michigan for 1906, p. 92. Also for 1908, p. 205.

agricultural purposes until properly drained and very often they are rendered "sour" by the large amount of humic acid present. When these two things are suitably attended to, the soil, the heavier varieties especially, are well adapted to root crops, with the exception of the sugar beet which is found to be of inferior quality. Excellent crops of onions, celery and peppermint are produced upon this type of soil, while the undrained bogs, when not sour, furnish the conditions required for the cranberry. The natural timber upon such areas was the tamarack, white cedar and spruce. With a subsoil of clay within reach of their roots, black ash and elm were also able to grow.

No analyses of muck soils from southeastern Michigan have yet been made but there may be appended here three analyses of similar Michigan soils, well known from the quality of celery produced upon them. These analyses show that about 1/5 to 1/4 of these soils consist of sand, that but very little clay (alumina) is present and that they are nearly 2/3 organic matter. They may be termed sandy muck and with an increase in the percentage of sand at the expense of organic matter would pass into black sand ("Clyde sand" of the Pontiac area). With clay present, instead of the sand, the muck may be characterized as a clayey muck and may pass into black clay. Within the county of Wayne, the areas of mucky soil are found in the immediate neighborhood of existing, or former swamps (see Pl. X) and scattered over the flood plains of the rivers.

TABLE XVI.—ANALYSES OF MICHIGAN CELERY SOILS.[19]

	Grand Haven.	Newberry.	Kalamazoo.
Sand and silicates	24.09	24.56	19.16
Alumina	1.71	2.21	1.40
Oxide of iron	3.52	1.30	3.04
Lime	5.02	4.18	6.09
Magnesia	.62	.75	.81
Potash	.20	.42	.34
Soda	.33	.40	.38
Sulphuric acid	1.04	.67	1.31
Phosphoric acid	.69	.46	.88
Carbonic Acid	1.05	1.10	1.95
Organic matter	61.73	63.75	63.76
Water	10.85	7.31	6.51

19. Kedzie, Michigan Soils: Bulletin 99, Michigan State Agricultural College, 1893, p. 12.

Amelioration of soils. The maintenance of soil fertility, combined with an actual increase in the same, are matters of much importance, primarily to the farmer and indirectly to the entire

community. This is one phase of the great question of conservation now before the public. Until the unwelcome truth has been forced upon him by gradually diminishing returns for his labor, the farmer has looked upon his land as an inexhaustible source of wealth, requiring only so much toil, rain and sunshine to yield returns. We have all learned by sad experience that bank accounts are sooner or later exhausted, if we continue writing checks and make no deposits. However rich the soil at the start, every load of grain harvested and every animal fattened upon it has reduced its resources by a certain calculable amount. The return of the straw and manure will greatly reduce the loss, but can not quite compensate. It is the height of folly to take from the soil as quickly as possible every dollar that it is capable of yielding and leaving it impoverished and temporarily worthless. A heritage in the shape of a patch of rich soil is a more valuable asset than a fat bank account, since banks occasionally fail and riches in the form of money oft "take wings."

Under the influence of natural agencies alone, in such humid climates as our own, soil is gradually brought to a state of fertility. The rain gathers annually from the atmosphere very appreciable quantities of ammonia and nitric acid which are brought to the soil and are subject to utilization by plants. Observations in Europe extending over a number of years indicate that the average annual amount of these two nitrogen bearing compounds is about 10.23 pounds to the acre, with a range of 1.86 to 20.91 pounds. This is estimated by King to be sufficient to supply the nitrogen for two bushels of wheat, were it all utilized. The observations of Failyer at Manhatten, Kansas, for the years 1887 to 1890, show a very appreciable but smaller amount.[20] Similar observations show that, for a rainfall equal to that of Wayne County, the amount of sulphuric acid brought to each acre is about 2¼ pounds. Small quantities of solid impurities are also washed from the atmosphere by rain and snow and contributed to the soil. Still larger quantities of dust and fine sand are swept across the country from the roadways and fields bare of vegetation. Clouds of such material may often be seen in the spring soon after the plowing. Rainwash from higher ground may also be spread over the adjacent land and add to its fertility. In some or all of these ways, fine material is gradually mixed in with the sands, giving them more body, supplying the variety of plant food needed and diminishing the average texture of the granules. Through the action of frost

20. Ammonia and Nitric Acid in Atmospheric Waters: Second Annual Report of the Kansas Experiment Station.

in disrupting the rock and mineral particles, the chemical action of the gases of the atmosphere, as well as that of the acids brought down in the rainfall, or produced in the soil itself, the soil particles are reduced in size and altered in character. Through this decay of the crystalline rocks there are added to the soil silica, alumina, carbonates of several kinds and varying quantities of soda and potash. The beneficial effects of the bare fallow upon most types of soil are thus accounted for.

Plant and animal agencies are also at work in bringing about a gradual improvement in the soil by loosening, mixing and the addition of organic matter. Plant roots often extend many feet into the ground and upon their decay leave the soil and subsoil more permeable to surface water and atmospheric gases, thus facilitating and extending downward the chemical changes required for a good soil. When plants are not removed from the soil in which they have grown, their decay returns to the soil all the mineral matter (ash) which they extracted from it and in addition certain substances derived from the atmosphere. Chief of these is carbon which but partially decays, as a rule, and helps to form the thin layer of surface mold. Certain plants, such as clover, beans, peas, etc., have the ability to extract from the air the free nitrogen and fix it into compounds not originally in the soil. This is done through the agency of the bacteria contained in the so-called "tubercles" upon their roots. This organic matter not only thus contributes to the soil food for future generations of plants, but renders the lighter soils more retentive of moisture and by giving them a darker color enables them to absorb more of the sun's heat in the spring when this is much needed for germination and early growth. Even dark colored heavy soils are also improved by the introduction of such organic matter, since they are rendered looser, more easily drained and more permeable to atmospheric gases. In its decay, this organic matter slowly liberates heat, by which the soil is slightly warmed, and in such decay organic acids are formed which assist greatly in rendering the minerals of the soil available as plant food. Animal substances introduced here and there would have the same result as that just given for plants. But while still alive, they are active agents in soil improvement. Darwin many years ago called attention to the great work done along this line by the common earthworm.[21] These creatures are often present in enormous numbers and in passing the earth through their long alimentary tracts, it is triturated, softened,

21. On the Formation of Mould: Transactions of the Geological Society of London, vol. V, 1840, p. 505.
The Formation of Vegetable Mould through the Action of Worms. 1881. Latest edition, 1907.

chemically changed by the digestive juices, and finally ejected upon the surface. Since they are known to penetrate to depths of nine feet it is readily seen that they must have much to do in mixing soil and subsoil, furnishing means for the admission of surface water and atmospheric gases to considerable depths and in thus deepening the layer of true soil. They have the habit further, of drawing into their burrows at night quantities of leaves and seeds which may there partially decay. Darwin estimated that in ordinary English soil, every five years, the equivalent of one inch of soil is thus worked over by these creatures (page 171), and, when continued through a series of years, their importance can scarcely be over estimated. They, however, are most active in a moist soil already rich which needs them the least. In drier, poorer soils we find the ants active, penetrating also to considerable depths, bringing subsoil to the surface and opening up channels beneath. Shaler has found the soils of certain fields in Massachusetts completely altered through their agency and estimates that annually one-fifth of an inch of soil is thus brought to the surface and exposed.[22] The larvae of numerous insects also burrow in the soil and bring about a similar result. Among the higher animals, there may be mentioned also the mice, gophers, woodchucks, ground squirrels, moles, muskrats, pigs, some birds, etc. The crayfish often constructs long, subterranean passages, terminating at the surface in a chimney-like structure made of subsoil materials. A prominent farmer of Summerfield township, Monroe County, informed the writer than one of his sandy fields had been very materially helped through their influence. Their passages also assist in securing better drainage for the soil, thereby contributing to its fertility.

Nature thus offers to the intelligent farmer many suggestions for the improvement of his soil, as well as for the simple maintenance of its original fertility. In very many instances, the subsoil may be brought nearer the surface by deep plowing to the great advantage of the soil. Clay may thus often be incorporated into a sand or mucky soil. In some instances, the necessary food materials of the plant have been leached from the soil proper and deposited in the upper layers of subsoil. Where clay or sand knolls occur their materials may often be gradually distributed to the advantage of the adjacent soils. The importance of adding manure to the soil is universally recognized by farmers today but the use of commercial fertilizers is not fully appreciated.

22. Origin and Nature of Soils: Twelfth Annual Report, U. S. Geological Survey, part I, 1891, p. 278.

Our State Agricultural College stands ready to offer expert advice along these lines and will gladly furnish bulletins to those interested in the scientific use of such material and in the rotation of crops. The occasional plowing under of a green crop, such as clover, is of great advantage to certain soils. In case a soil is too barren to produce clover in quantity, it is recommended that a commercial fertilizer be first used until a good "catch" can be secured. In this way, the fertility of an impoverished soil may be eventually restored. Lime, ground limestone, marl, gypsum ("plaster") and wood ashes often supply the ingredients lacking in a certain type of soil or act beneficially upon it, and a most interesting and profitable line of experiments may be carried on about every rural home in discovering what crops can be most advantageously grown and of just what assistance the soil stands in need.

The importance of free drainage in the case of soils naturally wet and cold is very generally recognized and this applies to all types of soils. This is especially true for the mucky soils that are liable to be "sour" from the presence of the free acids resulting from the decay of the organic matter. Such soils have a sour odor and when applied to blue litmus paper[23] in moist condition give a reddish coloration. Barren patches in mucky areas, sometimes not even producing weeds, are generally due to this cause. The condition may be remedied by the application of sufficient lime, wood ashes, or marl, the latter being often found underlying the muck itself and hence readily available. When the soil runs into a pure peat it has little value for agricultural purposes, but when underlain by clay or loam, it may be burned after complete drainage and a good soil thus obtained. An illustration of such improvement is shown in the northwestern corner of Romulus township where the peat occasionally catches fire and burns to a depth of 5 to 8 feet. This practice is, however, wasteful of valuable material which may be utilized in a variety of ways noted upon a subsequent page.

23. This may be obtained from almost any drug store.

Besides the data collected at the Detroit station, the U. S. Weather Bureau has secured less complete observations from volunteer observers at numerous stations in southeastern Michigan, which data, along with those supplied by the Canadian Meteorological Service, have been made the basis from time to time of meteorological maps covering the Great Lake region. Director C. A. Schneider of the Michigan State Service, prepared such a rainfall map of Michigan in 1900 and two years later Prof. A. J. Henry issued the latest precipitation map of the United States,[6] based upon records from 1871 to 1901, inclusive. Prof. Mark Jefferson has made, more recently, a careful study of the precipitation of the Great Lake region and constructed a map of Michigan and the territory adjacent, based upon the records for a period of 25 years.[7] The averages for stations at which the records were incomplete were "corrected" by comparing them with the averages of the corresponding years at nearby stations where the records were complete.[8] Although still but approximations, such corrected averages must represent more nearly the normal mean for such stations. A still later summary has just been issued by the U. S. Weather Bureau covering the precipitation and temperature at selected stations in the eastern half of the Lower Peninsula, those stations being selected which furnished the longer records.[9] The summaries here given include the year 1908.

Owing to the more or less intimate connection between precipitation and lake and Detroit River levels, records of their extreme stages throw light upon the cycles of precipitation during the 50 years that preceded the taking of definite meteorological observations, thus extending our record through a period of some 125 years. These early data, however, are fragmentary and more or less legendary and unreliable. The extremely high water of 1838 called attention strongly to the lake and river fluctuations and three observers were especially active in gathering all the data at that time available and in recording subsequent levels. Charles Whittlesey published his full data in 1859 under the title "On

6. Monthly Weather Review, April, 1902, p. 207.
7. Rainfall of the Lake Country for the Last 25 Years: Eighth Annual Report of the Michigan Academy of Science, 1906, p. 78. See also Material for Geography of Michigan, Normal College News, vol. III, No. 18, 1906, p. 159.
8. This correction is made by finding first the average for the full period at the reference station selected; next the average also for the identical years during which observations were made at the station which is to have its average corrected. Dividing the average for the full period by that for the limited period at the reference station gives a ratio by which the average at the second is to be multiplied in order to get the corrected result. The assumption is that the ratio between the average for the actual years of observation and the full series, could it have been made at the second station, is the same as that of the corresponding ratio at the reference station, where the complete series was actually made.
9. Summary of the Climatological Data for the United States, by Sections. Section 63, 1910.

ditional data then available, Dr. Henry T. Lyster, of the Michigan State Board of Health in 1878 prepared "A Study of the Climate and Topography of the Lower Peninsula of the State of Michigan.[3] Hubbard's observations and generalizations were finally brought together in a most readable volume entitled "Memorials of a Half-Century" (1888), in which 162 pages are devoted to the climatology of southeastern Michigan.[4]

The work of another voluntary observer should be also here mentioned, that of Rev. George Duffield, D. D., who kept a record of the Detroit climate from 1840 to 1857. The precipitation records, month by month, were published in the Report of the Board of Water Commissioners for the year 1858, page 16. Through the kindness of his son, Samuel P. Duffield, M. D., now of Detroit, the writer has learned that these data were collected at the northwest corner of what are now High Street and Woodward Avenue, just one mile back from the river (ground elevation 605 feet above sea level) and with a rain gauge manufactured by B. Pike and Son, of Philadelphia. The gauge was located in the garden and Dr. Duffield thinks may have been somewhat affected by "whirls" from the house in the case of certain heavy storms. The funnel of the gauge, five inches in diameter, he still retains but the glass graduate, which accompanied it, has been broken. The observations of Hubbard were made at the home still standing on Vinewood Avenue, between Lafayette and Howard streets, about one-half mile from the river, where the elevation is some 595 feet above sea level. The distance in a straight line from the Duffield home is about 2¼ miles. These details are mentioned in order to discover some possible explanation for the marked discrepancy in the two sets of precipitation data, those of Rev. Duffield being about 50% greater than those of Hubbard for the 17 years, 1840 to 1856, inclusive. It is known that gauges set at different levels and at no great distances show marked differences in their readings. Data of this nature were collected in New Orleans between 1895 and 1904 and reported in the Monthly Weather Review for May, 1905, page 204. Gauges were placed at different points in the city, the greatest distance between them being six miles. The means for the 10 years were respectively 52.80, 52.00, 49.85, 47.65 and 52.33 inches; but for single years variations of 10 to 12 inches were observed.[5]

3. Sixth Annual Report of the Michigan State Board of Health for the year 1878, pp. 169 to 210.
4. Through the kindness of Mr. Hubbard's daughter and her husband, Mr. Frederic Towle, of Detroit, the writer has secured possession of most of the original meteorological data and field notes of this distinguished pioneer geologist and meteorologist. It is expected that these will be eventually turned over to the library of the University of Michigan for preservation.
5. Jefferson, *loc. cit.*, below.

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9. Summary of the Climatological Data for the United States, by Sections. Section 63, 1910.

Fluctuations of Level in the North American Lakes"[10] and Bela Hubbard in his "Memorials of a Half-Century," 1888, page 461. A manuscript chart prepared by the latter is in the writer's possession showing lake and river levels from 1787 to 1894, with curves of rainfall and sun-spots for comparison. In his Second Annual Report, dated Feb. 4, 1839, Douglass Houghton devotes six of the thirty pages to the discussion of "Changes of Elevation in the Waters of the Great Lakes",[11] with the help of the "oldest inhabitants" going back to 1800. Based upon the scientific data supplied by the Smithsonian Institution, the War Department and the U. S. Lake Survey, Mr. Charles Crosman published in 1888 a complete chart of the five Great Lakes, with an explanatory booklet (Swain and Tate, printers, Milwaukee, Wis.). The chart shows the mean monthly and annual fluctuations of the surface levels and the rainfall curve for one or more adjacent stations, along with other interesting data, extending over the years 1859 to 1887: A similar chart but showing only the lake levels, was issued by the U. S. Lake Survey covering the years 1860 to 1904, inclusive. Since the year 1853, daily records of the level of the river have been taken for the Detroit Water Board. In their Forty-Ninth Report, published in 1901, a table is given showing the monthly high, low and mean levels for the years 1854 to 1900, inclusive. Partial data are also given extending back to the year 1819. It has been recognized by all observers that there is a direct connection between these lake and river levels and the general precipitation of the drainage basins into these lakes, the extreme stages of the levels lagging somewhat behind the corresponding precipitation stages. It has also been pointed out by Prof. Henry that the amount of evaporation from the surfaces of the lakes may have an important bearing upon their elevations and that a more or less complex relation may exist between their levels and precipitation, evaporation, strength and direction of winds and lake discharge.[12]

Precipitation. In the form of rain and snow, Detroit receives an average annual precipitation of 32.13 inches, as indicated by the 40 years' observations of the U. S. Weather Bureau (1871 to 1910). For the same period of time (1835 to 1874), but overlapping the former record by four years, Hubbard's average is 30.3 inches. This is as close agreement as we could expect in the case of records

10. Smithsonian Contributions to Knowledge, vol. XII, 1859, pp. 4 and 5. See also Second Annual Report of the Geological Survey of the State of Ohio, 1838, p. 51. Foster and Whitney's Report on the Geology of the Lake Superior Land District, pt. II, 1851, p. 319.
11. Senate Document No. 12, 1839, pp. 278 to 284.
12. Variations in Lake Levels and Atmospheric Precipitation: U. S. Department of Agriculture, Weather Bureau No. 203, 1899, p. 7.

obtained from separated and differently exposed gauges, for even the same series of years, and is a testimonial of the care and fidelity with which these early observations must have been taken and recorded. The total monthly and annual precipitation, with the averages for the entire period of 40 years, 1871 to 1910, is shown in table XVII.[13] about 33% of the precipitation occurs in May, June and July, just when it can be of the greatest service to the growing crops. The least monthly precipitation takes place in January, and mostly then in the form of snow. During the remaining eight months the precipitation is rather evenly distributed, as far as may be judged from the averages, ranging from 2.30 to 2.73 inches. The combined total for the winter and summer seasons is but slightly in excess of that for the spring and fall. The greatest precipitation for any single year since 1835 was 47.69 inches and occurred in 1880, due to abnormally heavy rainfall from April to September, inclusive. This represented an increase of 48.4% above the normal. The least annual precipitation for the entire period of 75 years was 21.06 inches in 1889, or only 65.5% of the normal, all months being deficient except May and December. During August of this year less than one-fifth of an inch fell, while, rather curiously, the previous August witnessed the heaviest 24 hour precipitation of the entire 40 year period, amounting to 4.42 inches.

13. The full data for this and the following tables is kindly supplied by Sgt. N. B. Conger and Observer C. D. C. Thompson, of the Detroit office of the Weather Bureau.

TABLE XVII.—MONTHLY PRECIPITATION DATA; U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU, DETROIT, MICHIGAN.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1871	2.01	2.42	2.62	1.55	2.34	3.88	1.94	1.21	1.43	.69	2.76	2.57	25.42
1872	.37	.69	1.22	2.15	5.64	2.85	2.63	2.60	3.84	1.60	.67	.69	24.95
1873	3.20	.32	1.79	4.94	3.50	5.18	3.43	.33	3.28	2.60	1.03	4.72	34.32
1874	4.96	2.00	1.55	1.39	1.93	4.53	3.65	2.11	.67	.78	2.26	.60	26.43
1875	.97	1.82	3.00	.70	5.83	3.25	3.73	6.04	2.10	3.35	1.72	3.20	35.71
1876	2.00	5.59	5.50	1.80	5.62	1.51	5.94	2.46	2.81	2.89	2.32	1.96	40.40
1877	1.23	.04	5.43	3.27	.90	4.80	1.57	7.29	.39	4.72	4.10	1.49	35.23
1878	3.04	2.58	3.35	2.06	2.77	3.36	8.76	2.92	3.74	2.89	3.10	4.83	43.40
1879	1.11	2.64	1.72	1.56	2.64	3.85	6.22	1.31	6.24	.83	4.71	4.62	37.45
1880	2.81	1.51	2.75	6.17	4.86	4.38	5.74	5.51	4.26	5.45	3.02	1.23	47.69
1881	2.39	6.41	3.36	2.37	2.45	5.90	3.33	1.32	2.86	6.52	4.36	4.17	45.44
1882	1.97	1.92	3.34	1.13	4.82	3.70	1.65	4.43	1.77	2.43	1.66	1.50	30.32
1883	1.69	3.22	1.55	1.53	5.11	4.32	5.29	.90	1.50	2.55	2.24	2.67	32.57
1884	2.08	3.39	2.10	1.54	2.38	1.92	3.76	1.55	2.70	1.96	1.74	3.05	28.17
1885	1.89	1.26	.66	1.74	3.65	3.36	2.83	5.05	1.54	1.68	2.19	2.30	28.15
1886	1.92	1.30	1.70	3.30	2.33	2.07	2.45	2.02	4.20	1.04	2.17	2.21	26.71
1887	1.31	4.16	1.44	1.19	2.11	4.19	1.31	2.30	4.41	1.49	2.72	2.34	28.97
1888	1.58	1.58	2.76	1.44	1.94	3.41	3.48	5.27	1.26	2.09	3.05	1.16	29.02
1889	1.51	.76	1.17	1.14	4.41	3.28	1.54	.19	.56	1.05	2.36	3.09	21.06
1890	2.70	2.01	1.32	2.74	3.94	4.28	1.69	4.46	2.31	5.67	2.64	1.23	34.99
1891	.92	3.07	2.23	2.72	1.68	2.28	2.90	2.86	1.33	1.93	5.30	1.61	28.83
1892	1.45	2.57	2.03	1.78	7.84	8.31	2.39	2.21	3.66	.30	3.10	1.47	37.11
1893	1.77	4.05	1.36	3.61	1.50	4.66	2.50	1.78	1.37	4.77	3.68	3.13	34.18
1894	.94	2.57	1.39	2.54	4.90	2.63	2.06	.16	2.47	3.37	1.15	1.56	25.74
1895	2.76	.22	1.69	1.31	2.61	.55	3.30	1.97	1.15	.56	4.19	4.73	25.04
1896	1.17	1.60	2.28	3.61	2.05	6.97	5.39	4.60	4.23	1.65	1.72	.93	36.20
1897	1.65	1.14	3.70	2.09	4.03	3.52	1.70	3.10	1.02	1.31	5.13	1.95	30.34
1898	3.32	3.27	3.11	1.51	1.65	5.15	2.03	1.84	3.30	3.49	2.92	2.75	34.34
1899	1.75	2.12	4.36	.53	3.38	1.82	2.95	.62	2.18	2.35	2.05	2.30	26.41
1900	1.14	4.30	3.26	1.64	3.08	3.99	3.71	2.08	1.88	2.85	3.10	.42	31.45
1901	1.52	1.64	1.80	2.07	2.76	2.08	3.50	3.20	1.65	1.90	1.00	3.66	28.78
1902	.57	.72	2.66	.60	3.52	6.97	7.55	.60	6.50	1.54	1.57	2.73	35.53
1903	1.63	3.19	1.36	5.51	1.55	6.32	4.59	4.27	2.78	1.67	1.18	1.83	35.88
1904	3.34	2.55	4.09	1.65	2.36	1.08	2.94	3.20	4.23	.86	.19	1.83	28.32
1905	1.93	1.50	1.02	2.20	4.31	4.44	3.52	4.18	3.27	1.15	2.76	1.72	32.00

TABLE XVII.—Concluded.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1906	1.90	.87	2.03	1.92	2.12	5.24	4.24	3.25	1.85	4.20	2.28	3.77	33.67
1907	3.87	.61	2.20	2.33	2.64	3.60	2.71	.62	4.10	1.86	1.46	4.62	30.62
1908	2.84	4.95	2.46	2.44	3.57	1.85	1.83	4.49	.56	1.49	.73	1.38	28.59
1909	2.51	4.26	1.71	4.25	3.78	4.95	5.94	3.75	.75	1.46	4.70	2.59	40.65
1910	3.14	1.84	.38	4.73	3.65	1.47	1.48	1.11	2.02	1.07	2.04	2.05	24.98
Average or "Normal"	2.04	2.32	2.34	2.41	3.30	3.80	3.50	2.73	2.55	2.30	2.53	2.42	32.13

In table XVIII, there has been compiled the snowfall, expressed in inches, for the years 1871 to 1910, inclusive, which may prove to be of interest for purposes of reference. From this, it is seen that the heaviest snowfall for any single year occurred in 1900, amounting to 73.3 inches, or over six feet. The great bulk of this fell in February and March, that for January and December being especially deficient. The least snowfall recorded was but 13.4 inches, for the year 1872. Upon an average, January contributes the most snow, February next in amount and March and December about the same. Scarcely an April passes without some snowfall, the average amount for the period covered by the Weather Bureau being 1.78 inches. In 1886, however, the amount recorded was 25.7 inches for this month. Only exceptionally is there any snowfall in May, but this occurred in 1875, 1883, 1892, 1900, 1902, and for the last seven years to 1912, with the exception of 1911. Snow in October is not so rare as in May, and November furnishes somewhat more than does April. The heaviest monthly snowfall recorded was for February, 1908, amounting to 38.4 inches, or 3.2 feet. In the last column of table XVIII, there is given the total fall for the continuous autumn, winter and spring seasons, instead of the total fall for any single year, which is shown in the column headed *annual*. That there exists a periodicity in the amount of snowfall, corresponding to that of the precipitation, will be pointed out in a subsequent paragraph, restoring again the "old fashioned winter", about which there centers many a winter tale.

Although the climate of Detroit may be considered as representing fairly the entire county, still owing to its altitude, location in the eastern part of the county and proximity to the lakes, minor variations appear when we study the data secured from the contiguous territory. The only other stations within the county are located at Plymouth and at Eloise, the site of the Wayne County Home, which is nearer the geographic center of the county and would presumably furnish better average climatic conditions than does Detroit. Unfortunately, however, the record at the latter place is short and incomplete. In the counties adjacent to Wayne, volunteer stations have been maintained, similar to those at Plymouth and Eloise, and, in table XIX, there is given the summaries for those stations which are most likely to throw light upon the climatic conditions that exist in the contiguous portions of Wayne.

TABLE XVIII.—TABLE OF SNOWFALL BY INCHES FOR DETROIT.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total annual.	Seasons total.*
1871											2.5	1.2		
1872	2.7	1.8	1.1	.4							1.5	5.9	13.4	9.7
1873	9.9	.9	3.2							1.4	4.2	2.1	21.7	21.4
1874	22.8	6.0									9.6	.7	39.1	36.5
1875	5.9	13.2	8.8	T	T								27.9	38.2
1876	20 0	18.6		T									38.6	38.6
1877	11.9	.4											?	
1878	30.4	11.1											?	
1879	6.9	18.8	3.1	1.1						T	5.4	8.8	44.1	
1880	.8	8.1	5.4	1.8						.4	6.9	6.2	29.6	30.3
1881	21.4	20.4	16.0	2.4								2.9	63.1	73.7
1882	1.5	1.9	4.1	T							3.5	8.2	19.2	10.4
1883	10.0	7.4	14.5	2.2	.1						.5	10.9	45.6	45.9
1884	20.8	2.8	1.4	.8						T	3.4	10.5	39.7	37.2
1885	6.0	2.1	2.4	6.2							.3	11.9	28.9	30.6
1886	8.4	5.3	8.6	25.7							.8	13.9	62.7	60.2
1887	11.4	4.6	4.2	.8							.3	4.3	25.6	35.7
1888	16.6	5.7	10.1							T	.9	1.2	34.5	37.0
1889	9.8	5.3	4.1	3.0							1.0		23.2	24.3
1890	1.6	4.0	9.1								3.2	11.9	29.8	15.7
1891	1.5	2.6	7.9	.6							6.8	5.4	24.8	27.7
1892	17.2	5.4	4.6	T	T						6.4	8.0	41.6	39.4
1893	23.1	18.0	1.5	2.7						T	2.7	16.6	64.6	59.7
1894	1.4	14.6	4.2	6.0							6.9	.4	33.5	45.5
1895	21.5	1.5	13.2	.1						.1	4.5	22.5	63.4	43.6
1896	2.6	6.5	10.5	.1						T	T	7.4	27.1	46.8
1897	8.7	8.2	10.4	T							.4	9.1	36.8	34.7
1898	11.4	19.6	2.5	.8						T	8.9	16.0	59.2	43.8
1899	4.2	6.5	24.1	.5							T	4.0	39.3	60.2
1900	5.4	28.0	30.2	1.5	T						6.2	2.0	73.3	69.1
1901	12.6	16.4	4.5	T						T	T	12.9	46.4	41.7
1902	5.4	5.4	1.2	.8	.5						5.1	13.8	32.2	26.2
1903	12.7	14.7	.1	4.9						T	2 3	12.3	47.0	51.3
1904	20.1	5.8	14.7	1.8							.8	7.5	50.7	57.0
1905	13 5	15.1	.2	.3							.3	4.8	34.2	37.4

TABLE XVIII.—Concluded.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total annual.	Seasons total.*
1906	7.3	1.6	2.5	1.0	T	....	....	....	....	T	1.2	7.1	32.6	17.5
1907	12.7	5.8	3.2	.8	.2	....	....	....	....	T	2.5	13.0	38.2	31.0
1908	12.2	38.4	1.8	.1	T	....	....	....	....	....	.3	6.9	59.7	68.0
1909	11.4	14.3	5.0	3.0	.4	....	....	....	....	.4	.3	14.7	49.5	41.3
1910	22.2	9.1	.1	T	T	....	....	....	....	T	2.3	20.1	53.8	46.8
Averages	11.4	9.6	6.6	1.8	....	....	....	....	....	....	2.5	8.2	41.9	39.8

*This column combines the snowfall for the consecutive fall, winter and spring.

TABLE XIX.—METEOROLOGICAL SUMMARIES FOR WAYNE COUNTY AND VICINITY.

(Data supplied by the Michigan, United States and Ontario Weather Bureaus.)

Station.	County.	Elevation above sea level.	Years of record.	Mean annual temperature. Degrees.	Mean annual precipitation. Inches.	"Corrected" with Detroit.	Average annual snowfall. Inches.	Prevailing wind.
Detroit	Wayne	730	40	48.2	32.13	32.13	41.9	SW.
Eloise	Wayne	640	14	48.9	29.45	30.02	35.9	SW.
Plymouth	Wayne	725	14	47.8	28.04	28.60	31.7	W.
Pontiac	Oakland	935	11	47.6	30.75	31.06	33.6	NW.
Ball Mountain	Oakland	983	20	46.0	32.14	32.78	42.6	SW.
Ypsilanti	Washtenaw	736	27	47.2	34.42	36.14	39.8	SW.
Ann Arbor	Washtenaw	930	31	47.0	31.77	32.09	38.5	SW.
Grape	Monroe	625	21	48.6	29.78	30.38	35.2	SW.
Windsor	Essex	626	34	47.7	30.80	30.65	37.9	SW.

An inspection of the preceding table shows that the Eloise and Plymouth records are for but 14 years, while that of Detroit runs continuously through 40 years. If the amount of precipitation maintained its average pretty closely, deficiencies or excesses of one year being promptly compensated for, the averages for Eloise, Plymouth and Detroit could be at once compared and conclusions drawn. However, an examination of the Detroit record shows that the average for the last 14 years is 31.54 inches, instead of 32.13 inches, that for the entire period. To reduce the 14 year average to that for the 40 years it is necessary to multiply it by the ratio $\frac{32.13}{31.54}$ or 1.02, and we may assume the same thing should be done for each of the other two stations. When the actual averages at the various stations are thus "corrected" with the Detroit record, it is found that they should all be slightly increased, for purposes of comparison, except the long Windsor record which is slightly reduced. This corrected column thus becomes necessary because of the fact, now of world-wide observation, that precipitation is in cycles. Although the actual range in precipitation is no greater than that which might occur within the limits of a single large city, still since these results represent *averages*, extending over a fairly long period, there are certain generalizations that seem justified. Some five years ago the writer pointed out that the precipitation over a belt of territory extending northeast and southwest across Monroe, Wayne and Oakland counties is somewhat less than that to the east and west.[14] These new figures, bringing the data to the close of the year 1910, show that this same condition still exists, the stations of Grape, Plymouth, and Eloise showing from 5 to 11% less precipitation than Detroit, and from 9 to 15% less than the average of the stations Ypsilanti, Ann Arbor and Ball Mountain, located in the high morainic section to the west. This slight reduction in precipitation might be assumed to be connected with the broad belt of sandy soil of this region were it not for the fact that the deficiency shows itself in the winter season as well as in the summer. The average annual snowfall at Grape, Eloise, Plymouth and Pontiac is less than that for Detroit, Ball Mountain, Ypsilanti and Ann Arbor, by a few inches. The phenomenon may be the climatic effect of the relatively high morainic belt that crosses Washtenaw and Oakland counties. For

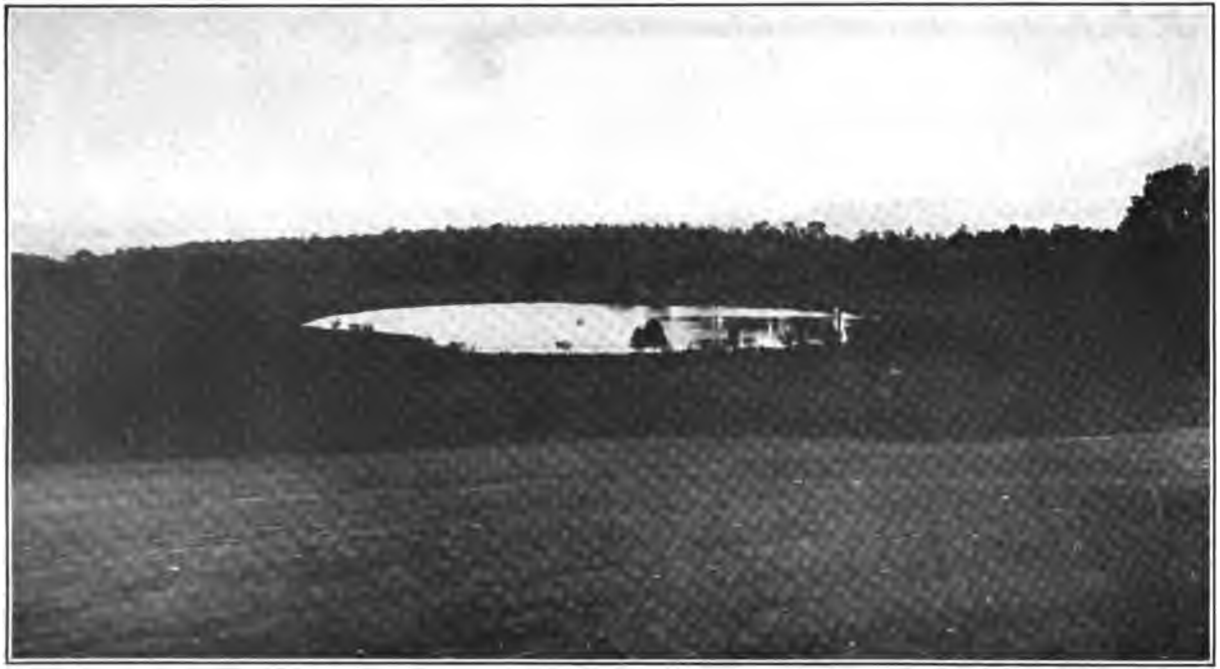
14. Water Supplies of Wayne County: Water Supply and Irrigation Paper, No. 182, U. S. Geological Survey, 1906, p. 49.

A. EFFECT OF PREVAILING WINDS UPON WILLOWS.

B. EFFECT OF PREVAILING WINDS UPON APPLE TREES.

UPPER MONROE STRATA, LIVINGSTONE CHANNEL, SHOWING THE LARGE CONCRETIONARY MASSES WHICH CHARACTERIZE SOME OF THE BEDS.

UPPER MONROE STRATA, LIVINGSTONE CHANNEL, SHOWING THE LARGE CONCRETIONARY MASSES WHICH CHARACTERIZE SOME OF THE BEDS.



VIEW OF YERKES LAKE, NEAR NORTHVILLE, THE ONLY NATURAL LAKE WITHIN THE LIMITS OF WAYNE COUNTY.

the entire county of Wayne, the average annual precipitation of the nine stations listed in the table would more nearly represent that for the county, the average at Detroit being too high and that at Eloise too low. The general average for the vicinity is 31½ inches, of which the equivalent of 3.75 inches, or 11.9%, falls as snow. This snowfall represents an average fall of 37½ inches, as ordinarily measured, ten inches of snow being regarded as the equivalent of one of rain.

The prevailing direction of the wind for the entire county is southwest, although at Plymouth, for the 14-year period it appears as west and as northwest at Pontiac. The average mean annual temperature for the nine stations is 47.7°F., the more elevated stations of Ann Arbor, Ypsilanti, Ball Mountain, and Pontiac being lower. For convenience of holding in mind, the climatic data for Wayne County may be summarized as follows:—mean annual temperature 48°; average annual precipitation 31 inches; average annual snowfall 3 feet; prevailing direction of wind southwest.

Temperature. The monthly and annual mean temperatures as determined by the Detroit station of the Weather Bureau (Fahrenheit scale) are given in table XX, from 1871 to 1910, inclusive.[15] The average of annual means is 48.2°F. for the 40 years of observation. Hubbard's average for the 40 years 1835 to 1874 was 47°, which was gradually raised to 47.9° by subsequent observations (see Memorials, page 450). The range in the mean annuals is from 43.2° to 52°, the highest being reached in 1881 and 1882 and the lowest in 1835. The highest average monthly mean is found in July (70.1°) and the lowest in January (24.5°). The highest monthly mean for any single year was 77° (July, 1901) and the lowest 12° (February, 1875). In tables XXI and XXII we have presented the extremes of temperature, maximum and minimum, for each separate month of the 40-year period, as indicated upon self-registering standard instruments. The highest such temperature was in July, 1887, reaching 101°, and the lowest—24°, December, 1872, giving an extreme range in 75 years of 125°. Hubbard noted an interesting relation between the temperature means for the various seasons, which relation is still as true as it was 25 years ago. When the mean of the three summer months (69.2°) is averaged with that of the winter (26.0°) we have a close approxi-

15. The monthly means represent the average of the daily means, obtained by adding the daily maximum and minimum readings of the thermometer and dividing by two. The mean annual for any year is obtained by taking the average of its monthly means. The writer can find no statement as to how Hubbard's daily means were obtained.

mation (47.6°) to the annual mean (48.2°). Similarly the spring mean (45.6°) when averaged with that of the autumn (51.3°), gives a still closer approximation (48.6°) to the annual. If the twelve months are arranged in three groups, by selecting one and skipping two, the average of their means again gives the same approximate result. The average of the mean for January, April, July and October is 48.1°; that of February, May, August and November is 47.7°; of March, June, September and December is 48.2°, showing a pretty even balance in the average distribution of the annual temperature.

TABLE XX.—MONTHLY AND ANNUAL MEAN TEMPERATURES AT DETROIT STATION OF U. S. WEATHER BUREAU.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1871	26	26	39	45	58	66	69	70	58	54	33	23	47.2
1872	23	24	26	47	56	68	73	72	63	49	33	19	46.1
1873	20	23	31	42	56	69	72	71	61	48	32	33	46.5
1874	29	27	34	38	59	69	71	69	66	51	38	27	48.2
1875	15	12	28	40	57	66	70	67	60	46	34	33	44.0
1876	32	28	30	44	57	69	73	72	59	46	39	18	47.2
1877	19	34	26	45	56	66	72	71	64	54	39	38	48.7
1878	27	29	41	53	55	64	74	71	64	52	39	23	49.3
1879	21	22	34	45	59	65	73	69	59	60	38	29	47.9
1880	37	32	33	46	64	68	71	69	62	49	30	22	48.6
1881	17	26	34	45	64	64	75	74	72	56	44	41	51.0
1882	31	40	40	46	53	67	70	71	64	58	42	30	51.0
1883	22	25	30	46	54	68	71	67	59	51	44	33	47.5
1884	20	31	35	46	59	70	70	69	68	56	40	30	49.5
1885	23	17	26	45	57	66	74	67	63	51	42	33	47.0
1886	24	28	36	51	59	67	72	71	65	55	39	24	49.2
1887	23	28	30	46	63	68	76	69	60	48	38	29	48.2
1888	18	24	29	43	54	66	71	69	60	47	41	31	46.1
1889	30	19	37	46	57	64	71	70	63	47	40	39	48.6
1890	34	32	30	46	55	72	72	67	60	52	41	27	49.0
1891	29	31	31	48	56	68	67	70	68	51	36	36	49.2
1892	21	29	31	45	56	70	72	71	63	52	36	27	47.8
1893	15	22	33	44	55	70	73	70	62	53	38	28	46.9
1894	30	24	40	48	56	71	74	69	66	52	35	32	49.8
1895	20	18	28	49	60	71	70	71	67	45	38	30	47.2
1896	25	25	29	51	65	68	71	70	60	48	40	30	48.5
1897	23	27	35	45	55	65	75	68	66	56	39	28	48.5
1898	28	26	40	45	59	70	73	72	67	53	37	27	49.8
1899	24	20	29	50	60	69	72	72	60	56	43	29	48.7
1900	28	21	26	48	60	67	72	76	67	60	39	29	49.4
1901	25	16	33	48	57	69	77	72	65	53	36	25	48.0
1902	25	23	39	47	58	64	73	68	62	52	47	27	48.8
1903	24	26	41	47	61	63	73	67	64	53	36	22	48.1
1904	18	16	33	41	59	67	71	68	64	50	40	26	46.1
1905	20	18	38	44	57	67	71	71	65	52	38	32	47.8

TABLE XX.—Concluded.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1906	34	26	28	49	58	68	71	74	68	51	40	29	49.7
1907	26	21	39	39	51	64	71	68	63	47	38	30	46.4
1908	26	22	36	45	59	68	73	70	69	54	40	30	49.3
1909	29	20	33	43	56	67	71	72	61	47	45	23	48.0
1910	25	22	44	49	54	66	74	71	63	55	36	23	48.5
Averages	24.6	24.7	33.4	45.7	57.6	67.3	70.3	70.1	63.5	51.7	38.6	28.6	48.2

TABLE XXI.—MAXIMUM TEMPERATURES AT DETROIT.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1871	57	59	64	80	87	90	88	95	85	81	50	54
1872	46	49	54	77	84	91	91	90	91	80	50	38
1873	54	52	53	64	83	90	94	90	86	78	56	57
1874	58	51	67	73	89	93	97	93	97	75	68	52
1875	41	51	75	75	86	90	86	84	88	75	59	65
1876	65	54	62	69	85	88	90	87	77	72	68	42
1877	48	58	50	75	86	85	90	88	83	84	57	58
1878	50	52	68	77	78	92	100	90	85	79	53	42
1879	44	42	67	76	87	91	94	93	82	85	69	59
1880	57	60	53	75	85	91	93	88	87	75	59	46
1881	37	54	53	78	90	88	95	99	94	75	66	60
1882	56	58	64	71	70	86	88	86	84	77	69	50
1883	50	58	58	78	77	87	91	89	81	78	67	58
1884	52	64	62	70	81	90	89	90	89	85	62	60
1885	53	50	55	77	80	87	90	86	81	72	67	55
1886	55	54	61	82	83	89	92	89	85	77	65	52
1887	54	54	52	72	87	88	101	93	90	75	64	55
1888	42	46	65	82	79	94	91	91	84	72	70	55
1889	49	49	65	76	88	86	91	90	85	76	64	65
1890	66	63	57	74	84	94	96	92	85	74	66	48
1891	50	53	52	79	81	88	89	96	93	85	64	58
1892	53	50	55	71	82	91	96	92	86	77	62	58
1893	46	42	66	76	85	89	93	92	87	81	62	60
1894	50	54	72	78	83	94	96	92	91	76	64	55
1895	49	52	62	80	95	96	93	92	94	70	68	59
1896	42	58	63	85	90	86	91	95	84	74	65	56
1807	58	44	57	73	79	89	94	84	93	88	59	54
1898	57	56	69	66	77	93	94	97	95	85	64	49
1899	50	55	58	84	84	90	90	92	95	79	58	59
1900	49	62	46	80	86	87	92	94	92	84	68	52
1901	50	34	66	83	85	90	94	88	88	78	63	58
1902	40	54	64	81	87	84	91	86	83	75	69	46
1903	53	50	73	79	87	86	92	84	88	75	71	39
1904	42	45	62	73	88	87	96	85	86	77	68	56
1905	47	36	77	72	80	89	94	90	87	81	61	48

TABLE XXI.—Concluded.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906	65	60	54	76	87	94	91	91	90	74	59	50
1907	60	47	75	72	81	87	86	86	83	76	54	53
1908	45	49	74	78	85	90	94	95	91	78	64	50
1909	61	52	53	74	81	87	90	92	87	75	70	59
1910	43	46	81	75	76	95	96	91	84	82	61	38

TABLE XXII.—MINIMUM TEMPERATURES AT DETROIT.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1871	5	3	24	35	40	52	54	54	37	33	13	−10
1872	−5	Zero.	−7	25	36	51	60	52	42	33	5	−24
1873	−12	−7	1	30	39	55	50	55	37	22	7	12
1874	Zero.	8	12	9	30	44	54	49	41	27	4	6
1875	−15	−20	Zero.	8	29	38	52	45	35	24	7	5
1876	9	4	7	25	30	50	53	46	39	24	16	−9
1877	−5	16	−2	20	32	42	54	56	43	34	11	18
1878	Zero.	7	16	31	33	42	56	51	39	24	24	−4
1879	−15	−3	14	16	30	39	54	48	34	26	12	−2
1880	19	11	11	24	33	49	52	48	35	30	Zero.	−11
1881	−2	−5	15	16	36	44	54	53	50	37	19	24
1882	8	20	23	24	33	46	53	50	42	37	20	2
1883	−8	6	3	18	32	46	50	49	30	34	14	11
1884	−6	−6	3	30	36	48	51	46	45	28	14	−6
1885	−7	−12	−2	30	30	44	54	48	41	28	29	1
1886	−4	−3	6	23	40	49	54	52	43	36	19	2
1887	−3	1	7	18	45	50	54	49	34	22	16	7
1888	−3	−7	2	23	30	45	50	46	35	30	22	13
1889	7	−8	17	22	34	42	53	52	36	25	16	19
1890	5	12	4	25	32	45	52	46	39	29	21	10
1891	14	2	6	21	29	42	49	48	47	28	10	17
1892	−3	4	10	22	35	52	50	52	45	30	16	−1
1893	−10	−6	9	26	37	51	55	52	34	26	16	6
1894	−3	−11	12	24	34	38	48	47	39	29	17	−3
1895	−4	−8	2	25	33	46	48	51	36	23	11	7
1896	−6	−3	4	18	43	45	52	49	33	30	13	2
1897	−16	4	13	20	36	41	57	49	39	37	18	−2
1898	2	−4	16	18	37	49	49	51	47	30	14	4
1899	−4	−13	11	22	39	49	56	53	30	32	29	Zero.
1900	−2	−2	−2	26	35	48	51	60	41	40	18	11
1901	1	−1	2	29	36	42	56	56	40	28	16	−6
1902	Zero.	−4	10	28	34	46	49	51	40	31	22	8
1903	−5	−4	19	22	28	47	50	47	41	28	13	1
1904	−6	−9	13	22	38	50	51	49	40	29	16	12
1905	Zero.	−15	15	27	30	47	53	55	45	28	15	16

TABLE XXII.—Concluded.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906	12	−2	8	26	31	42	52	56	45	25	21	8
1907	−2	−5	14	19	30	44	52	49	38	29	21	15
1908	2	−2	17	22	31	44	50	50	41	31	18	11
1909	4	Zero.	15	21	30	48	54	50	39	26	24	−1
1910	2	3	17	31	34	39	51	48	48	26	26	7

As pointed out by Winchell and Hubbard, the influence of the great bodies of water upon the climate of the lake region is clearly perceptible, when comparisons are made with those localities to the east or west, or even in the interior of the lower peninsula. This influence is shown by the modification of the extremes of temperature, the summer maximum being lower and the winter minimum higher than for places to the east or west upon the same parallels. The monthly means are also similarly modified and the spring and autumn seasons are prolonged, giving a more gradual passage from winter into summer and from summer into winter. This is indicated in the dates of last killing frosts in the spring and the first in the autumn, these being given in table XXIII. The averages of these two dates are May 1st and October 12th, and the latest and earliest were May 31st (1897) and September 21st (1871).

TABLE XXIII.—DATES OF KILLING FROSTS AT DETROIT, MICHIGAN.

Year.	Last in spring.	Year.	First in autumn.
1871	No record.	1871	September 21.
1872	No record.	1872	October 24.
1873	No record.	1873	October 7.
1874	May 7.	1874	October 13.
1875	May 6.	1875	October 12.
1876	May 1.	1876	October 9.
1877	May 2.	1877	October 5.
1878	May 15.	1878	October 19.
1879	May 2.	1879	September 25.
1880	May 14.	1880	September 30.
1881	April 9.	1881	October 21.
1882	May 2.	1882	October 20.
1883	April 29.	1883	September 26.
1884	May 29.	1884	October 15.
1885	April 9.	1885	October 21.
1886	May 8.	1886	October 2.
1887	April 19.	1887	October 22.
1888	May 18.	1888	September 29.
1889	May 28.	1889	September 27.
1890	May 11.	1890	October 21.
1891	May 17.	1891	October 13.
1892	April 26.	1892	October 5.
1893	April 21.	1893	September 26.
1894	April 9.	1894	September 25.
1895	May 21	1895	September 30.
1896	April 8.	1896	September 23.
1897	May 31.	1897	November 3.
1898	April 6.	1898	October 27.
1899	April 9.	1899	September 30.
1900	April 14.	1900	November 8.
1901	April 21.	1901	October 18.
1902	April 5.	1902	October 21.
1903	May 1.	1903	October 24.
1904	April 22.	1904	October 7.
1905	May 1.	1905	October 25.
1906	May 10.	1906	October 10.
1907	May 11.	1907	October 14.
1908	May 2.	1908	October 9.
1909	April 26.	1909	October 14.
1910	April 13.	1910	October 28.

Average date of last killing frost in spring, May 1.
Average date of first killing frost in autumn, October 12.

Winds. The passage of the weather *spells* across the country from west to east, as is so generally the case for the Lake region, accompanied by changes in the pressure of the air, influences greatly the direction of the wind. The direction of wind, thus determined, exerts a very marked effect upon temperature and precipitation. In a very strict sense then, the climate of Wayne County is largely determined by the number, intensity, direction, course, and velocity of these weather spells, which move in from the Pacific, as a rule, cross the country and pass off into the Atlantic. Any variation in these factors would lead to a corresponding alteration of climate. Without any such movement of these weather breeding areas, southeastern Michigan would have some kind of a climate, of course, but it would be a very different one from that which we are called upon to describe. In table XXV we have the prevailing direction of the wind given for each month of the Weather Bureau series, with also the average of each and the prevailing direction for each particular year. Perhaps it should be stated that by "prevailing direction" is meant the quarter from which the wind blew more frequently than from any other, regardless of whether or not this number constituted a majority of the entire monthly, or annual series. In case of "tie" both directions have been inserted, either for the month (March, 1871), or for the year (1875). An inspection of the table shows the great prevalence of westerly winds, ranging from southwest, through west to northwest; the prevailing direction for ten months of the year being southwest.

In March, the direction is slightly in favor of west, with northwest and southwest following in order. In April alone does the wind prevail from an easterly quarter, being then northeast, but with southwest next in order. Of the entire 40-year series only once did a southeast wind prevail for an entire month, this being in August, 1885, which month was characterized by 5.05 inches of rainfall, or 85% above the normal for this month. The full data for this month, along with others furnishing still heavier precipi-

TABLE XXIV.—YEARS OF HEAVY AUGUST RAINFALL, DETROIT.

Year.	Rainfall.	Percentage of normal.	Mean temperature.	Percentage of normal.	Prevailing wind.
1875.......	6.04 in.	221%	67°	96%	SW.
1877.......	7.29 in.	267%	71°	100%	SW.
1880.......	5.51 in.	202%	69°	98%	SW.
1885.......	5.05 in.	185%	67°	96%	SE.
1888.......	5.27 in.	190%	69°	98%	SW.

tation, are shown in the following table for ready comparison, from which it will appear that this extra rainfall is not to be attributed to the direction of the wind. In March, 1871, the "prevailing direction" was evenly divided between southeast and northwest, with only a small excess of precipitation beyond the normal (12%). North and south winds do not often prevail; the former being found most frequently in spring (April) and the latter in autumn (October). Taken by years, the southwest wind has greatly prevailed over all others combined, represented by 30 of the 40 years of observations. Rather curiously for three years (1881, 1884, 1885) a south wind prevailed, but with no very marked effect upon the mean annual temperature. In 1881, the south wind prevailed through September, October, November and December and for these four months alone the precipitation was 56% of the entire annual. In the other two years, however, the precipitation was below normal, both for the totals and for the months during which the south winds prevailed, so no generalizing is permissible.

The direction of prevailing winds has given a set to the trees of most orchards (Pl. XXII, A) and to many of the native trees, apple and willow (Pl. XXII, B) being especially susceptible and are often found inclining strongly to eastward. In planting new orchards, it is advisable to give them a slight slant to westward in order to counteract this effect of the wind. Where the trunks of the less yielding native trees are not actually inclined, the tips of the twigs and smaller branches will be found bent toward the east and the head unsymmetrically developed, the greater bulk lying on the eastern, or leeward side.[16] The long continued falls of rain and snow are generally ushered in with a southeast wind; while the lighter falls and sudden storms are preceded by winds in the southwest. The continued heavy blows, so destructive to shipping, are often from the northwest. Winds of tornadic violence are very infrequent in occurrence, Hubbard during the entire 50 years of his recorded observations noting but one such (Memorials, pages 541 and 544). Upon the afternoon of Sunday, June 27, 1875, a writhing, funnel-shaped cloud, of inky blackness, struck the northwestern portion of the city a few minutes before six, destroying some twenty-one cottages, killing two people outright and injuring a score of others. The path of the tornado was from southwest to northeast, crossing Grand River Avenue nearly at right angles, between 12th and 18th Streets.[17] At the time of the

16. This wind effect has been especially described by Prof. M. S. W. Jefferson: Journal of Geography, vol. III, No. 1, 1904, p. 3.
17. The Detroit Post, June 28 and 29, 1875.

TABLE XXV.—PREVAILING DIRECTION OF WIND AT DETROIT.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1871	S	W	SE NW	NE	SW	NW	SW	SW	SW	SW	NW	W	SW
1872	SW	NE	W	E	W	SW	SW	SW	SW	SW	W	W	SW
1873	SW	NW	NW	E	E	E	W	NE	SW	W	W	W	W
1874	SW	E	NW	NE	SW	E	SW	E	SW	SW	W	SW	SW
1875	W	W	NE	W	W	SW	SW	SW	SW	W	N	SW	W SW
1876	W	W	NW	W	E	SW	SW	SW	E	SW	W	SW	SW
1877	SW	SW	NW	NE	SW	SW	SW	SW	SW	SW	W	SW	SW
1878	W	SW	SW	NE	W	SW	SW	SW	SW	SW	W	W	SW
1879	SW	W	W	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW
1880	SW	SW	W	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW
1881	SW	E	W	NW	E	E	W	N E	S	S	S	S	S
1882	W	W	W NW	W	NE	E	SW	E	E	S	W	W	W
1883	SW	W	W	N	N	SW	W	W	NE	NW	W	SW	W
1884	SW	N	N	N	S	E	W	S	S	S	SW	S	S
1885	S	SW	S	NE	S	S	S	SE	SW	S	SW	W	S
1886	W	SW	E	E	SW	N	NE	SW	SW	SW	W	W	SW
1887	W	NW	N	W	E	W	W	E	NE	SW	SW	W	W
1888	W	SW	W	NW	W	S SW	NE	SW	SW	SW	NW	S	SW
1889	SW	W	NW	NW	SW	SW	SW	SW	SW	NW	SW	SW	SW
1890	SW	NW	NW	N	W	SW	SW	NW	W	NW	SW	SW	SW
1891	SW	SW	NE	NW	NE	SW	SW	SW	SW	SW	SW	SW	SW
1892	SW	NE	NE	NE	SW	SW	SW	SW	SW	SW	SW	SW	SW
1893	SW	SW	SW	SW	SW	SW	SW	NE	NW	SW	SW	SW	SW
1894	SW	SW	SW	NE	SW	SW	SW	SW	SW	SW	SW	SW	SW
1895	SW	NW	NE	NE	SW	SW	SW	SW	SW	SW	SW	SW	SW
1896	SW	SW	NW	SW	SW	NE	SW	SW	SW	SW	SW	SW	SW
1897	SW	SW	NE	SW	SW	SW	NE	SW	SW	NE	W	W	SW
1898	W	SW	W	NE	SW	SW	SW	SW	SW	SW	SW	SW	SW
1899	SW	SW	W	W	SW	SW	SW	NE	SW	NE	SW	SW	SW
1900	SW	W	NE	NE	SW	NE	SW	SW	SW	SW	SW	SW	SW
1901	W	W	SW	N	NE	SW	SW	NE	SW	SW	NW	SW	SW
1902	W	W	SW	W	NE	W	SW	NE	SW	SW	SW	SW	SW
1903	W	SW	SW	NE	NE	NE	W	NE	SW	SW	SW	SW	SW
1904	SW	NE	W	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW
1905	SW	SW	SW	W	SW	SW	W	SW	SW	SW	SW	SW	SW

TABLE XXV.—Concluded.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1906	SW	SW	W	W	W	SW	NE	SW	SW	SW	W	SW	SW
1907	W	W	W	NW	SW	S	W	W	W	NW	W	SW	W
1908	SW	W	SW	SW	E	S	E	S	S	S	SW	W	SW
1909	SW	SW	NW	E	E	SW	S	E	N	SW	S	W	W
1910	NW	SW	E	E	N	E	S	E	E	W	NW	NW	NW
Average	SW	SW	W	NE	SW	SW	SW	SW	SW	SW	SW	SW	SW

Ypsilanti tornado, April 12, 1893, an extreme wind velocity of 120 miles per hour was noted in Detroit for five minutes but no particular damage occurred in the county as the result. An unusually heavy wind storm, of much greater extent and of essentially different character from the tornado ("cyclone" of the papers) swept across southeastern Michigan on the evening of June 4, 1911. Thousands of trees were uprooted, or snapped off by the wind; old orchards, shade trees and open woodlots suffering especially, the trees being thrown in the main to the S. SE. Some damage, considerable in the aggregate, was done to roofs and chimneys and an occasional building was entirely demolished by the direct force of the wind.

Weather cycles. The careful studies of Hubbard based upon accurate data covering some 50 years (1835 to 1888), led him to discover the cyclic character of both rainfall and temperature and that high annual temperatures were associated with minimum precipitation and low temperatures with maximum precipitation (Memorials, 1888, page 470). He endeavored to connect these cycles with those maximum and minimum periods of sun-spots, which have been found to average 12.3 years since 1769. In summarizing, he says, "The periods of maximum and minimum sun-spots, temperature and rainfall have an intimate relation to each other, and that this relation appears in the respective periodicities, which differ but little, while the means are nearly identical" (page 479). From charts and tables he showed an apparent relation between maximum numbers of sun-spots and low water stages of Lake Erie, diminished precipitation and high temperature, with the reverse of these conditions accompanying the stage of minimum spots. He then sagely adds, "It may be that all these cycles are but members of a grander whole, whose circles reach beyond our present ken" (page 480).

The work of connecting sun-spots with terrestrial climate, such as precipitation, temperature and atmospheric disturbances, had been previously undertaken by numerous writers (Baxendell, Blanford, Stewart, Smyth, Stone, Köppen, Meldrum, Poëy, Lockyer, Hunter, Dawson, etc.) and an intimate relation shown. A similar relation had been demonstrated between sun-spots and terrestrial magnetic phenomena (See reference to Lockyer and Hunter's paper noted in foot note 20).

In studying the long-period oscillations of the level of the Caspian Sea, Brückner reached the conclusion that there was indicated a 35-year cycle, which seemed to be connected with the stages of

water of the rivers emptying into it and hence with the precipitation of the entire basin.[18] Fuller studies of the fluctuations of other lakes and rivers of the world, in connection with precipitation and temperature, led this author to conclude that there exists a 35-year climatic cycle, made up of a cold, damp phase, followed by a warm, dry one.

Other investigators have collected data which tend to confirm the conclusions of Brückner,[19] relating to numerous phenomena, more or less closely associated with variations in precipitation and temperature. These are the advance and retreat of the extremities of glaciers, the dates of the opening and closing of rivers of Europe, the dates of the vintage in central Europe, and, in Norway, the years of harvest and those in which the crops failed to ripen. It was shown by Brückner that the price of grain in Europe during the wettest and coldest lustrum of the cycle averaged 13% higher than during the driest portion. In regions of lower latitude where the reduction of temperature is of less importance and the success or failure of the crop depends upon the amount of precipitation during the growing season, the wet phase of the cycle brings prosperity to the farmer; the dry phase may bring failure and possibly starvation. Lockyer and Hunter as early as 1877, in a paper entitled "Sun-spots and Famines", endeavored to connect the precipitation cycles with the famines in India.[20] Ward has shown that the rural depression in the central states, west of the Mississippi, appeared with the coming on of a dry phase of Brückner's cycle.[21]

In the year 1905, Prof. E. E. Bogue, of our Michigan Agricultural College, showed that a connection probably exists between the amount of precipitation and the thickness of the rings of growth in trees.[22] Four years later Prof. A. E. Douglass, of Tucson, Arizona, published the results of a very detailed study of the rings of growth of the pines growing near Flagstaff, some of them over 500 years of age.[23] In this study Prof. Douglass found evidences of cycles of growth recorded in the tree sections, the longer of which averaged 32.8 years, and which he believed to be connected with the precipitation cycles.

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18. Klimaschwankungen seit 1700, nebst Bemerkungen über die Klimaschwankungen der Diluvialzeit, 1890. Zur Frage der 35-jährigen Klimaschwankungen: Petermanns Geogr. Mitteilungen, Heft VIII, 1902, p. 1.

19. Hann, Ueber die Schwankungen der Niederschlagsmengen in grösseren Zeiträumen: Sitzungsberichte der kaiserlichen Akademie der Wissenschaften (Wien), CXI, 2a, 1902, p. 1.

Oyen, Klima—und Gletscherschwankungen in Norwegen: Zeitschrift für Gletscherkunde, I Band, 1906, p. 46.

Richter, Geschichte der Schwankungen der Alpengletscher: Zeitschr. deutsch. österr. Alpenver. (Vienna), 1891, p. 1.

20. Nineteenth Century, II, 1877, pp. 594 to 602.

21. Is our Climate Changing: Chicago Record Herald, March 25, 1906.

22. Monthly Weather Review, June, 1905, p. 250.

23. *Idem*, June, 1909, p. 225.

In order to show to what extent the climatic data of southeastern Michigan are in harmony with the theory above outlined, the two following tables are presented. Table XXVI is based upon European data, where alone sufficient observations are available for the construction of such a long series table. Still less reliable data carry the record as far back as the year 961. Table XXVII gives the annual precipitation and mean annual temperature for the Detroit station, with the excess, or deficiency, of each when compared with the average for a long series of years. From 1835 to 1870, inclusive, the averages of Hubbard were used (30.7 inches and 47.6°, respectively), and from 1871 to 1910 those of the U. S. Weather Bureau (32.13 inches and 48.2°). An inspection of the column of precipitation departures shows clearly that there are series of years in which the excess and deficiency are very marked. By taking the algebraic sum of these departures we obtain the *accumulated* excess, or deficiency, for the period and this is indicated in the table. When thus grouped it is most evident that for 75 years the precipitation of this region has been in cycles, each made up of a dry and a wet phase, and that these phases have a more or less close correspondence with those of other parts of the world (see table XXVII). The grouping of the years of the Detroit record was made, however, without any reference to others and could be made to correspond more nearly by transferring a few of the years near the margins of the series, about which there must necessarily be uncertainty as to which group they properly belong. From 1884 to 1901 in this region, there was marked deficiency, amounting to 48.85 inches, or the equivalent of a full year and a half of normal precipitation. During this phase, many wells went dry and had to be deepened, flowing wells lost head and were much reduced in volume. Well drillers were in demand and statistics would probably show a wave of prosperity in this line of business and in well supplies in general. It was of interest to note that the wells that actually failed to yield water during this phase were usually those that had been made during the preceding wet phase of the cycle, that is, from 1875 to 1884. Those that dated from the preceding dry phase could generally still be relied upon for a diminished yield. The records for the years 1902 and 1903 made it appear that the dry phase had closed, and a new, damp phase entered upon; but the marked deficiencies of 1904, 8, 10 leave the matter somewhat in doubt. However, since 1901 there is still an accumulated excess of 1.07 inches (to the close of 1910) for these nine years and data from other stations are needed to decide

whether or not we have actually entered upon a wet phase. In the 65 years from 1837 to 1901, inclusive, there have been 2½ complete cycles, or an average of but 26 years to the cycle. The two years, 1835 and 1836, seem to represent the closing of a damp phase which was responsible for the long remembered and much talked of "high water of 1838". It seems not improbable that the averages of a longer series of years will give a longer cycle. The data referred to at the opening of this chapter enable us to extend the series backward nearly 50 years farther, if we conceded that stages of level of the lakes and Detroit river indicate abnormal precipitation in the years immediately preceding. Hubbard states it as admitted (Memorials, page 464) that the water was higher in 1838 than at any known period. Very high water is also traditionally reported in 1814-15, 1800-02, and again in 1788. The lowest level known to the old Frenchmen at Detroit occurred in the year 1819, but was also reported as very low in 1796. These records indicate fluctuations within the Brückner cycles and enabled Hubbard to connect so successfully the lake levels with sun-spot frequency. From the exceptionally low water of 1819, the water gradually rose and culminated in the high stage of 1838, lagging some two years behind the phase of excessive precipitation. This low water stage of 1819 appears as the culmination of the preceding dry phase, but does not harmonize with the European phase shown in table XXVI, indicating that there are other factors besides quantity of precipitation to be reckoned with in the matter of the lake levels of this region. Lake Huron is reported to have been lower in 1810-11 than in 1819, and although this date is more nearly in harmony with the phase of precipitation in other portions of the world, it still represents considerable retardation.[24]

24. See Lane, Geological Report on Huron County: Geological Survey of Michigan, vol VII, 1900, part II, p. 44.

TABLE XXVI.—CLIMATIC OSCILLATIONS AND EFFECTS.

Based upon European data.

Precipitation.		Temperature.		Lake Levels.		Glaciers.	
Damp.	Dry.	Cool.	Warm.	High.	Low.	Advancing.	Retreating.
1591-1600		1591-1600				1595-1610	
			1601-1610				
1611-1635		1611-1635				1630	
			1635-1645				
1646-1665		1645-1665				1677-1681	
			1665-1690				
1691-1715		1691-1705				1710-1716	
	1716-1735		1706-1735		1720		
1736-1755		1731-1745		1740		1735	
	1756-1770		1746-1755		1760		1750-1767
1771-1780		1756-1790		1777-1780		1760-1786	
	1781-1805		1791-1805		1798-1800		1800-1812
1806-1825		1806-1820		1820		1811-1822	
	1826-1840		1821-1835		1835		1822-1844
1841-1855		1836-1850		1850		1840-1855	
	1856-1870		1851-1870		1865		1855-1875
1871-1885		1871-1885		1880		1875-1893	
	1886-	1886-			1892-		1894-

When table XXVII is inspected for evidence of a similar and corresponding temperature cycle, there is little to attract attention, the plus and minus departures following along as they might be expected to do if Nature was bent upon rendering hasty compensation. During the dry phase 1884 to 1901, the accumulated excess of temperature, to be sure, was 3.8°, or about 8% of the normal, but this seems slight in amount. Since 1901 (to 1910) the accumulated deficiency is but 1.1°. During the wet phase 1875 to 1883, with an excess of rainfall amounting to nearly two full years, instead of a corresponding deficiency in heat received, there was a slight excess, indicated by 1.4°. A similar, but even more pronounced reversal occurred during the wet phase of 1848 to 1863, and during the dry phase 1837 to 1847 there was a temperature *deficiency*. When examined year by year it is seen that years of especially heavy rainfall, such as 1880 and 1881, had also a mean annual temperature slightly above, instead of below the normal. A recent writer upon the subject has called attention to the fact that the relation of sun-spot frequency to terrestrial temperature is most clearly shown when only the temperature of the coldest month is considered, or the average is taken of the two coldest months.[25] When this is done, however, for the Detroit temperature monthly records, no more satisfactory results are obtained than when the yearly means are used. Based upon the Detroit data alone, there is little

25. Uber elfjährige Temperaturperioden, Dr. A. Magelssen, Christiania, Norway: Meteorologische Zeitschrift, Band 28, September, 1911, Beilage, p. 5.

TABLE XXVII.—CLIMATIC CYCLES AT DETROIT.[26]

Year.	Precipitation in inches.	Departure from normal.		Temperature, Fahrenheit.	Departure from normal.	
1835	32.2	+1.5	+11.10	43.2°	−4.4°	−7.7°.
1836	40.3	+9.6		44.3	−3.3	
1837	27.2	−3.5	Accumulated deficiency 26.40 in.	44.4	−3.2	Accumulated deficiency 3.2°.
1838	28.0	−2.7		46.0	−1.6	
1839	24.8	−5.9		48.4	+0.8	
1840	29.3	−1.4		47.2	−0.4	
1841	27.2	−3.5		46.3	−1.3	
1842	31.8	+1.1		48.8	+1.2	
1843	27.5	−3.2		45.7	−1.9	
1844	32.9	+2.2		48.8	+1.2	
1845	22.3	−8.4		48.6	+1.0	
1846	29.7	−1.0		49.8	+2.2	
1847	30.6	−0.1		46.4	−1.2	
1848	31.7	+1.0	Accumulated excess 27.10 in.	48.5	+0.9	Accumulated excess 6.4°.
1849	33.8	+3.1		49.0	+1.4	
1850	25.8	−4.9		49.6	+2.0	
1851	32.0	+1.3		46.5	−1.1	
1852	33.7	+3.0		47.3	−0.3	
1853	29.0	−1.7		49.5	+1.9	
1854	34.7	+4.0		48.9	+1.3	
1835	43.0	+12.3		48.3	+0.7	
1856	28.8	−1.9		45.0	−2.6	
1857	32.0	+1.3		43.3	−4.3	
1858	35.7	+5.0		49.9	+2.3	
1859	29.0	−1.7		48.3	+0.7	
1860	27.8	−2.9		48.4	+0.8	
1861	38.7	+8.0		48.6	+1.0	
1862	31.8	+1.1		48.8	+1.2	
1863	30.8	+0.1		48.1	+0.5	
1864	26.0	−4.7	Accumulated deficiency 28.40 in.	48.1	+0.5	Accumulated excess 1.1°.
1865	22.3	−8.4		45.2	−2.4	
1866	31.7	+1.0		46.3	−1.3	
1867	27.0	−3.7		48.0	+0.4	
1868	37.0	+6.3		51.3	+3.7	
1869	30.6	−0.1		51.7	+4.1	
1870	29.3	−1.4		48.5	+0.9	
1871	25.42	−6.71		47.2	−1.0	
1872	24.95	−7.18		46.1	−2.1	
1873	34.32	+2.19		46.5	−1.7	
1874	26.43	−5.70		48.2	0.0	
1875	35.71	+3.58	Accumulated excess 59.04 in.	44.0	−4.2	Accumulated excess 1.4°.
1876	40.40	+8.27		47.2	−1.0	
1877	35.23	+3.10		48.7	+0.5	
1878	43.40	+11.27		49.3	+1.1	
1879	37.45	+5.32		47.9	−0.3	
1880	47.69	+15.56		48.6	+0.4	
1881	45.44	+13.31		51.0	+2.8	
1882	30.32	−1.81		51.0	+2.8	
1883	32.57	+0.44		47.5	−0.7	
1884	28.17	−3.96	Accumulated deficiency 48.85 in.	49.5	+1.3	Accumulated excess 3.8°.
1885	28.15	−3.98		47.0	−1.2	
1886	26.71	−5.42		49.2	+1.0	
1887	28.97	−3.16		48.2	0.0	
1888	29.02	−3.11		46.1	−2.1	
1889	21.06	−11.07		48.6	+0.4	
1890	34.99	+2.86		49.0	+0.8	
1891	28.83	−3.30		49.2	+1.0	
1892	37.11	+4.98		47.8	−0.4	
1893	34.18	+2.05		46.9	−1.3	
1894	25.74	−6.39		49.8	+1.6	
1895	25.04	−7.09		47.2	−1.0	
1896	36.20	+4.07		48.5	+0.3	
1897	30.34	−1.79		48.5	+0.3	
1898	34.34	+2.21		49.8	+1.6	
1899	26.41	−5.72		48.7	+0.5	
1900	31.45	−0.68		49.4	+1.2	
1901	28.78	−3.35		48.0	−0.2	

26. Based upon the observations of the U. S. Weather Bureau for the years following 1870 and for the previous years upon the work of Hubbard, as deduced from his published tables; the actual figures for each year not being found amongst his papers.

TABLE XXVII.—Concluded.

Year.	Precipitation in inches.	Departure from normal.		Temperature, Fahrenheit.	Departure from normal.	
1902	35.53	+3.40	Accumulated excess 1.07 in.	48.8°	+0.6°	Accumulated deficiency 1.1°.
1903	35.88	+3.75		48.1	−0.1	
1904	28.32	−3.81		46.1	−2.1	
1905	32.00	−0.13		47.8	−0.4	
1906	33.67	+1.54		49.7	+1.5	
1907	30.62	−1.51		46.4	−1.8	
1908	28.59	−3.54		49.3	+1.1	
1909	40.65	+8.52		48.0	−0.2	
1910	24.98	−7.15		48.5	+0.3	

indication of a temperature cycle that can be correlated with the precipitation cycle of Brückner and this may be due to its proximity to the Great Lakes, causing it to partake to this extent of the character of his "exceptional coast stations."

Brückner in searching for an explanation of his climatic cycle considered the matter of a long period sun-spot variation, but accepting the supposed 55-year period of Wolf, he was led to reject this explanation (Klimaschwankungen, *loc. cit.*, p. 242). Admitting that the heat derived from the earth's interior is practically constant and so slight in amount as to have no appreciable effect upon our climate, we must, however, look to the sun as the chief source of energy concerned in climatic change. From *a priori* considerations, we should expect to find there only the cause of phenomena so completely involving the surface of the earth. Periodic activity in solar energy might reasonably be expected to exert some kind of periodic effect upon terrestrial climate. The times of maximum sun-spots are known to represent such stages of maximum solar activity, the spots furnishing an index, as remarked by Lockyer, but not a measure of such activity. Observations with suitably placed thermometers have shown that the earth receives at such times a great heat wave, with a period of 11 to 12 years. With this recognized solar periodicity we need not be surprised to find some corresponding terrestrial effects, as noted; shown in rainfall, temperature, atmospheric disturbance, magnetic phenomena and auroras. This, however, accounts for the minor climatic waves rather than the Brückner cycle of about 35 years. It is a very suggestive fact that this cycle is approximately three times that of the recognized sun-spot period and the remark of Hubbard (previously quoted) assumes significance. The real explanation sought may be furnished in the discovery of Lockyer (W. J. S.) that

there exists a long-period sun-spot variation of 35 years, controlling the terrestrial, climatic cycle.[27] He says, "Having found that, in addition to the well-known eleven-year period of sun-spot frequency, there is another cycle which extends over about thirty-five years, and which is indicated clearly, as has been shown, both by the changes in the time of the occurrence of the epochs of maxima and in the variations in area included in consecutive eleven-year periods of both sun-spot and magnetic curves, it is only natural to suppose that this long-period variation is the effect of a cycle of disturbances in the sun's atmosphere itself (p. 296). Such a cycle, if of sufficient intensity, should cause a variation from the normal circulation of the earth's atmosphere, and should be indicated in all meteorological and like phenomena."

As to the economic importance of a knowledge of the existence of such weather cycles, much might be written. The old adage "forewarned is forearmed" applies with great force and should lead to the conservation of food supplies in those regions in which the reduction of rainfall, or temperature, means suffering and loss of life. The planning of irrigation projects in advance of their need, methods of agriculture by which moisture is conserved and the introduction of special crops requiring a minimum of moisture may prove to be the solution of this serious problem. But even in this region where the oriental type of famine is unknown, these weather cycles mean to the farmer added labor, expense, annoyance and often complete discouragement. If we have actually entered upon the wet phase of the longer cycle, about which there may be some reasonable doubt, we may expect a succession of moderately cool summers, snowy winters, freedom from excessive drought and considerable precipitation. Land that is low-lying should be well provided with effective drains, and old drainage channels opened so as to provide the best possible flow. Wells now put in should be deep enough to allow considerable lowering of the ground water level and still supply sufficient water. If this is not done, the next dry phase may require a deepening of the well and added expense. When this phase arrives, and it is certain to do so, sooner or later, the farmer who has learned the method of "dry farming" will be well repaid. In the vicinity of Detroit River, schemes for the small scale irrigation of truck farms would be found feasible. If other factors could be eliminated, it would probably be found that the prices of farm lands fluctuate with the precipitation cycles and hence with the sun-spots. In closing his discussion of the subject Hubbard in 1886 wrote,

27. The Solar Activity, 1833-1900: Proceedings of the Royal Society of London, LXVIII, 1901, p. 285. Nature, LXIV, 1901, p. 196.

"The new century, though opening with cold and wet, gives promise, in its first cycle, of returning general prosperity, inaugurated by abundant crops, and if the nation be wise—by freer trade, restored commerce, satisfied wages, and solid wealth. Blessed be the sun-spots!"

Weather prediction. The forecasting of the weather for from one to three days ahead of its actual arrival may now be done with considerable satisfaction and many practical results. The principles employed may be readily mastered and should be taught and practiced in all our public schools, rural and urban.[28] Every rural home and school should have a weather-vane, rain gauge, simple barometer and a reliable thermometer. Where there is free rural delivery service, the daily weather map may be obtained from the Local Weather Station, at Detroit, and will be found of great service in individual forecasting. Upon these maps, the "high" and "low" areas may be noted, often several days in advance of their arrival, and their course across the country watched.

The lows, or cyclonic areas, are preceded by a drop in the barometer, indicating less atmospheric pressure, a swinging of the wind into the south, a rise in temperature, moist atmosphere, cloudy skies and generally rain or snow. With the passage of the area directly across the region occupied by the observer, the wind dies away and springs up from the north, with a cessation of precipitation, clearing skies, lower temperature, and rising barometer. Should the center of the area cross the country far enough to the southward, there appears a southeast wind, accompanying a relatively slight fall of the barometer, which wind moves around to the east and then northeast. In case the center of the area passes to the northward, there appears first a southwest wind, swinging to the west and then the northwest.

A relatively rapid drop in the barometer indicates that a storm of considerable intensity is approaching with corresponding velocity. A slow, gradual drop suggests a storm of slight intensity, moving slowly, or one of greater intensity with its center to the north or south of the observer. The key to an understanding of

28. From the U. S. Weather Bureau, Department of Agriculture, Washington, D. C., the following bulletins may be obtained gratuitously:
Bulletin No. 184, upon the use and care of instruments.
Bulletin No. 191, "Weather Forecasting."
Explanations of the Weather Map.
See also "Weather Bureau and the Public School," Weeks: Yearbook of Agriculture for 1907.
"Meteorology in School," Davis: School Review, vol. II, p. 229.
"Our Heralds of Storm and Flood," Grosvenor: National Geographic Magazine, vol. XVIII, 1907, p. 586.
Storms and Weather Forecasts, Moore: National Geographic Magazine, vol. VIII, 1897, p. 65.
About the Weather, Harrington, 1899. D. Appleton & Co.
Weather Folklore and Local Weather Signs, Garriott: U. S. Weather Bureau.
Elementary Meteorology, Waldo, 1896. American Book Co.

the behavior of the winds is furnished by the statement that there exists about such an area of low pressure a great whirl in counter-clockwise direction, the winds moving spirally in toward the center and there rising, well illustrated in miniature by the small whirls often indicated by dust, leaves, etc. In the case of these small whirl-winds, however, both the clockwise and counter-clockwise movements are represented.

In the case of the so-called high, or anti-cyclonic areas, regions of higher barometric pressure, with a descending current at the center and a clockwise, outwardly directed spiral, the above conditions are exactly reversed. Such an area very generally follows a low, being ushered in by the north wind of the latter, the two working together like great atmospheric wheels geared together. Cooler temperature, higher barometer, fair or clearing skies, dry atmosphere and absence of precipitation are accompaniments, to be followed upon the western border by the southerly wind and probable approach of the inevitable low. When the weather map is available, the procession of low and high areas across the country may be watched; their course, velocity and intensity noted and their final approach indicated by the barometer, wind-vane, thermometer and condition of the sky, along with the ordinary weather signs. Without the weather map, less satisfactory work can be done but the intelligent farmer may obtain from the meteorological reports of the daily press more or less information of what to expect, and with the help of his instruments need not often be taken by surprise. Although he can not as yet control the amount of precipitation, it is a matter of much interest and some importance to measure and record the amount of rain and snow, 10 inches of the latter being regarded as equivalent to one inch of the former. The time required for such weather observations is so small as to be neglectible, the instruments will pay for themselves many times over, there is satisfaction and profit in better shielding one's self, family, stock and crops against sudden or extreme changes and intellectual pleasure in thus pitting ones wits against the elements.

DIAGONAL SYSTEM IN WAYNE COUNTY.

Struck with the frequency with which the directions northeast, southeast, southwest and northwest entered into descriptions of the physical features of the state of Michigan, Alexander Winchell, in 1873, read a paper before the American Association for the Advancement of Science entitled "The Diagonal System of the Physical Features of Michigan.[29] This diagonal characteristic is shown

29. American Journal of Science, 3rd series, vol. VI. 1873, p. 36. Michigan (extracted from Walling's atlas), 1873, p. 32.

very strikingly in Wayne County in practically every natural feature and has left a strong impress upon those forms of construction for which man himself is responsible. Some of the original causes have no apparent connection but they have all conspired to bring about the same result. Subsequently to the formation of the great rock strata:—shale, limestone, dolomite and sandstone—that underlie the glacial deposits of southeastern Michigan, a great force disturbed their horizontality and established a slight dip to the northwest. This gave their outcropping edges a northeast-southwest trend, permitting the formation of a system of parallel troughs in the softer strata by weathering and stream erosion. The harder, projecting ridges formed northeast-southwest divides and between them lay belts of preglacial soil derived directly from each type of rock. Along these similar belts of soil the vegetation of previous geological ages must have secured its distribution, and to a greater or less extent, also the animal life directly, or indirectly dependent upon it.

The passage of the great Labradorean ice sheets across the region, from the northeast to the southwest, very nearly coincided with the *strike* of the rock strata and cleared out the troughs, deepening and broadening them to an extent. Owing to the direction of ice movement and the course of the ice margins, the morainic ridges and boulder belts were located as described in chapters II and III, with a general northeast-southwest trend, with parallel depressions between the surface slopes to the southeast or northwest. This general surface slope gave direction to the main streams and their tributaries as also described. The only ones following the chief points of the compass being the North Branch of the Rouge, deflected from its natural course by the Detroit moraine, some of the tributaries of Brownstown Creek, similarly deflected by the Grosse Isle moraine, and the lower half of Detroit River. The higher morainic features of the county gave direction to the shore lines of the series of lakes whose history was traced in Chapter II, and thus determined the direction of the belts of gravel, sand and clay. These types of soil in turn determined the direction of the belts of natural and cultivated vegetation and the distribution of animal forms. The belts of artesian water, of natural gas, underground water flow, economic materials; also of equal temperature, prevailing wind, and of rainfall have a diagonal distribution in the county. The direction of the sand and gravel ridges still further determined the course of many of the Indian trails, as it did also that of a number of the early highways, which the rectangular survey has been unable to completely efface.

In the days of early French occupancy, each claimant of govern-

ment land was allowed any amount, up to 640 acres, for the surveying of which he was willing to pay. With no system of roads yet established the streams were the main highways and each farm must have its waterfront. As a result, the claims were laid out at right angles to the larger stream courses, extending back as narrow strips and thus partook of the same diagonal features as of the stream courses. This arrangement brought each claim into harmony with the natural distribution of the soil and permitted equable tillage and crop management. With the cabins facing the water and the patches of cultivated land arranged with the claims, it so happened that the various farm and household activities, as well as those of the neighborhood, were either parallel with, or at right angles to the streams. This was true also for the private lanes, the roadways between claims and those cutting across the claims, near the streams and a mile or more back. The old lake beaches often determined the location and facing of farm houses, stores, schools, churches and cemeteries. The city of Detroit is laid out on a plan fundamentally determined by the course of the river and there are but a few short unimportant streets in the northeastern and northwestern corners of the city that run with the main points of the compass. The arrangement of the streets and alleys has, of course, determined the direction of the artificial drainage (gutters and sewers); of the street railways; the facing of all buildings, with their internal arrangements and multifold activities to the most minute details. The location of the city of Detroit was determined by the moraine, upon the crest of which it stands, and to reach it there has been built an elaborate system of diagonal steam and electric railways. The steamship and ferry lines move either with, or across the strip of river opposite the city. It thus becomes apparent that practically all of the natural features of the county and many of the most important artificial constructions and lines of movement, affecting all of the people some of the time and probably 90% of the people all of the time, are traceable back to certain geological forces that operated diagonally across the county long before the advent of man. These 90% are still eating, sleeping, being educated, being transported, working, taking recreation, worshiping and will eventually be buried upon the *bias*. There is no reason to believe that it will be different with future generations. The far-reaching factors, whose influence we have thus traced, are but single links in the long chain that reaches indefinitely backward as well as forward and are now beyond human ken.

CHAPTER VI.

HARD-ROCK GEOLOGY.

MISSISSIPPIAN SYSTEM.

With the progress of geological knowledge in the United States it has been ascertained that the long recognized, but poorly named *Carboniferous* system, consists of three distinct groups of strata. These have been variously known as:

1. Subcarboniferous, Mountain limestone, Carboniferous limestone, Early or Lower Carboniferous, Mississippian.
2. Carboniferous proper, Upper Carboniferous, Coal Measures, Pennsylvanian.
3. Permian, Upper Barren Coal Measures.

The term "Subcarboniferous" was first used by David Dale Owen in 1838 for an extensive series of sandstones, shales and limestones lying below the Coal Measures, but including also Devonian and Silurian strata.[1] The term was soon restricted to include those strata only of later age than the Devonian and constituting the base of the Carboniferous series. As thus restricted, it was known to have a wide distribution in North America, attaining its maximum thickness in the Appalachians but also well developed in the Mississippi region where it consists largely of limestones. The term *Mississippian* was proposed for the formation by Williams in 1891[2] and has come into quite general use in the more recent literature. This is a slight modification in form and usage of the terms proposed by Alexander Winchell, some 12 years earlier, the "Mississippi limestone series or Mississippi group."[3] In their recent Geology (vol. II, 1906, page 508) Chamberlin and Salisbury proposed advancing the Mississippian to the rank of a distinct system, coördinate with Devonian, Silurian, etc., and thus separating it from the Coal Measures or Pennsylvanian.

Within the limits of the state of Michigan the Mississippian comprises four sets of strata, which in ascending order are,

1. Report of a Geological Reconnoissance of the State of Indiana; made in 1837; 1838, pp. 12 and 13.
2. Correlation Papers, Devonian and Carboniferous: Bulletin No. 80, U. S. Geological Survey, 1891, p. 135. To this bulletin is referred the reader who is interested especially in the nomenclature and correlation of the various formations described in this chapter.
3. The Marshall group: Proceedings of the American Philosophical Society, vol. XI, 1879, p. 79.

1. Berea sandstone.
2. Coldwater shales.
3. Marshall sandstone.
4. Grand Rapids group; dolomite, limestone, shale and gypsum.

Of these only the first two, or lowest, cross the county of Wayne and hence fall strictly within the limits of this report. They are, however, under a heavy burden of drift and are only very imperfectly known from well borings.

Coldwater shales. Where exposed in Branch and Hillsdale counties the Coldwater shales (from their good exposures along Coldwater River)[4] are seen to consist of light colored, thin-bedded, shales, with occasional bands of limestone, becoming sandy towards the top as they pass into the overlying Marshall. Occasionally there occur irregular nodules of brownish, kidney iron ore, often mistaken by drillers for limestone or sandstone.

These shales have been utilized in Branch County in the manufacture of Portland cement and numerous analyses have been made. The following table shows their range in composition in the vicinity of Coldwater.[5]

TABLE XXVIII.—ANALYSES OF COLDWATER SHALE, NEAR COLDWATER, MICHIGAN.

(Analyst H. E. Brown).

Silica, (SiO_2)	57.26 to 61.25%
Alumina, (Al_2O_3)	18.12 to 21.59%
Ferric oxide, (Fe_2O_3)	6.53 to 8.30%
Calcium oxide, (CaO)	1.25 to 1.50%
Magnesium oxide, (MgO)	1.49 to 2.31%
Sulphuric anhydride, (SO_3)	.65 to 1.34%
Carbon dioxide, (CO_2)	.95 to 1.18%
Titanium oxide, (TiO_2)	.82 to 1.12%
Alkalies, (Na_2O and K_2O)	2.25 to 3.45%
Loss on ignition (H_2O and organic matter)	6.19 to 8.32%

According to Lane, the minimum thickness in the state is 600 feet, giving a broad exposure beneath the drift from Hillsdale and Lenawee counties northeastward to Lake Huron, crossing the northwestern corner of Wayne. Upon the Lake Huron shore, good exposures of the shale occur at White Rock Point and Forestville, Sanilac and Huron counties. As in the case of all the strata to be described the *dip* of the formation is to the northwestward, giving a northeast-southwest *strike*. Were the drift completely removed from the Southern Peninsula, the outcropping edges of the strata would be seen encircling the central (Saginaw) basin, dipping towards and under it, suggestive of a nest of wooden

4. Lane, The Geological Formations of the Lower Peninsula and their Economic Products: Geological Survey of Michigan, vol. V, pt. II, 1895, p. 19. See also by same author Notes on the Geological Section of Michigan, Pt. II, From the St. Peters up: Annual Report of the State Board of Geological Survey of Michigan for the year 1908, p. 43.

5. Russell, The Portland Cement Industry in Michigan: Twenty-second Annual Report of the Director of the U. S. Geological Survey, part III, 1902, p. 666.
Ries, Clays and Shales of Michigan, their Properties and Uses: Geological Survey of Michigan, vol. VIII, pt. I, 1900, p. 42.

butter-bowls. The younger and geologically higher formations are hence found toward the northwest, the older and geologically lower toward the southeast. Originally the entire series was approximately horizontal and seems to have been deformed about the close of the Palaeozoic era by the pronounced subsidence of the Saginaw area. Within the limits of Wayne County, there are no well sections that penetrate the Coldwater series from which the thickness could be determined. In the village of Plymouth, a 280-foot well (Alfred N. Brown, driller) showed 25 feet of gray shale at a depth of 100 feet of drift. A stratum of sandrock yielded a flow of fresh water which rose to within two feet of the surface. Beneath was reported 10 feet of excessively hard "conglomerate rock" and 15 to 20 feet of sandstone, underlain by limestone. About one mile west upon the place of Dwight Berdan (NW. 1/4 SW. 1/4 sec. 27), a light flag-stone was entered six inches at a depth of 122.5 feet. The Plymouth record would indicate that we are there near the eastern margin of the series of lighter colored shales. Toward the northwest, more of them should be encountered just beneath the drift and less and less to the southeastward, until they give out completely. In the deep wells of Ypsilanti and Ann Arbor, we have more complete data relative to the geological series of the county. Four of these records are here reproduced from the Ann Arbor Folio (1908, page 3).

TABLE XXIX.—SECTION OF CORNWELL WELL, YPSILANTI.

On flood plain of Huron. Elevation of mouth about 680 feet.	Thickness in feet.	Total depth in feet.
Earth, clay, gravel, sand, etc., unconsolidated	109	109
"Slate" (probably shale)	241	350
"Flint"	5	355
Sandstone	38	393
Soft "slate" or sandstone (sandy shale)	157	550
"Bedrock" (hard limestone?)	200	750

TABLE XXX.—SECTION OF ATLANTIS WELL, YPSILANTI.

(From manuscript notes by Alexander.Winchell.)

Near Normal College Campus. Surface elevation about 785 feet.	Thickness in feet.	Total depth in feet.
Sand, clay, gravel, etc., unconsolidated	185	185
Shale, soft	4	189
Sandstone, fine, slightly calcareous	10	199
Limestone, fine; all dissolves in acid	10	209
Shale, dun, dark; lower 74 feet black	84	293
Shale, sandy, dun	64	357
Sandstone, very fine, slightly calcareous; yields bromine water	4	361
Limestone, pale, cherty	10	371
Shale, sandy	5	376
Limestone, ranging from pale and cherty to dun and sparry	43	419
Shale, bluish to dun, in places gritty	22	441
Limestone, varying from siliceous to pure	24	465
Shale	21	486
Limestone, varying from pale to dun, with some shaly partings, portions magnesian, others siliceous; contains sulphurous (H_2S) water	138	624
Unrecorded	184	808

TABLE XXXI.—SECTION OF COURT HOUSE WELL, ANN ARBOR.

(Record of Dr. Carl Rominger.)

Surface elevation 835 feet.	Thickness in feet.	Total depth in feet.
Soil, gravel, clay, etc., (glacial deposits) (According to Winchell thickness of drift is 164 feet.)	155	155
Shale, blue, arenaceous, with seams of fine-grained sandstone	150	305
Shale, black, bituminous, with gas and drops of oil	28	333
Sandstone, gray, with brine	92	425
Shale, blue, with sandstone layers, and seams of pyrite	100	525
Shale, black, very bituminous, with pyrite	85	610
Shale, dark blue, arenaceous, with pyrite, traces of fossils	22	632
Shale, black, bituminous, with pyrite	68	700
Limestone, bluish, cherty	70	770

TABLE XXXII.—SECTION OF CAMPUS WELL, UNIVERSITY OF MICHIGAN, ANN ARBOR.

(Record by Dr. A. C. Lane, based upon drillings.)

Surface elevation 880 feet.	Thickness in feet.	Total depth in feet.
Quaternary:		
Coarse, cross-bedded sand and gravel	90	90
Blue, boulder clay	145	235
Coldwater shale:		
Blue shale	30	265
Pinkish shale	15	280
Fine gray, sandy shale	75	355
Fine soft, gray and black shale	20	375
Fine gray, sandy shale	10	385
Fine bluish shale	15	400
Berea sandstone:		
Fine gray sandstone	15	415
Fine sandy shale	25	440
Glossy black shale	5	445
Fine gray, sandy shale	75	520
(Salt water at 515 feet.)		
Antrim shale:		
Fine black and greenish shale	10	530
Fine gray, sandy shale	15	545
Very fine, black shale	15	560
Black, bituminous shale	15	575
Coarse, gray sandstone	5	580
Black, sandy shale	20	600
Black, bituminous shale	80	680
Traverse formation:		
Shale with pyrites	5	685
Gray, calcareous shale	60	745
Dundee limestone:		
Gray, cherty limestone	25	770
Light-gray limestone	30	800
Gray, argillaceous limestone	130	930
Monroe formation:		
Light-gray dolomite	40	970
Gray dolomite containing sand	60	1,030
Light-gray dolomite with Sylvania sand grains	205	1,235
Pure white friable sand (Sylvania)	35+	....

Well stopped at 1,326 feet in the Sylvania.

The most satisfactory record of the series is that of the University well drilled in 1899-1900, the drillings of which were examined by Lane, then state geologist, with a detailed knowledge of the various formations obtained from a study of the rocks in outcrop. This record assigns 165 feet to the Coldwater and shows that it is composed of pinkish, bluish, gray to black shale; in places somewhat sandy. The Court House well gives 178 feet of shale, above the sandrock, which appears referable to the Coldwater. In passing southeastward to the Cornwell well in Ypsilanti, some 7½ miles, the rock surface drops 74 feet, but there still remain some 241 feet which are to be considered as belonging to this same formation. In the Atlantis well and that of the Banner Oil and Gas Company, the sandstone stratum, marking the base of the Coldwater series, is not recognizable with certainty. Lithologically this formation is very similar to the Cuyahoga formation of Ohio, named by Newberry in 1870,[6] and as restricted by Orton[7] and later by Prosser[8] is very nearly its geological equivalent. The Berea shale, or Sunbury shale, however, is separated from the Cuyahoga in Ohio while it is intended to be included in the Coldwater of Michigan.[9] Lane in his latest discussion of the formation (1909) makes it the equivalent of the Sunbury, Cuyahoga, Buena Vista and Raccoon, of the Ohio series, and the lithological equivalent of the Portage and Chemung of New York.

Berea sandstone. This formation was originally defined by Lane[10] as the Richmondville sandstone and was regarded as the geological equivalent of the Berea grit of the Ohio series. Since then, however, he concluded that the "Richmondville" is not the exact equivalent of the Berea "but a stray sandstone somewhat higher up."[11] It constitutes the base of the Coldwater series although the two can not always be separated with certainty in the well records because of the frequent occurrence of sandstone strata in the Coldwater. In southeastern Michigan, the formation is a coarse, gray sandstone, 100 or more feet in thickness. Farther north in Huron County and at Tawas and Oscoda this sandrock supplies brine and in Wayne County what appears to be the course

6. Newberry, Geological Survey of Ohio, Report of Progress in 1869, pt. I, 1871, p. 22 Also Report of Progress in 1870; 1871, p. 469.
7. Orton, Geological Survey of Ohio, vol. VI, 1888, p. 37. Vol. VII, 1893, p. 31.
8. Prosser, The Nomenclature of the Ohio Geological Formations: Journal of Geology, vol. XI, 1903, p. 519. See also The American Geologist, vol. XXXIV, 1904, p. 335, and Bulletin No. 7, Fourth Series, Geological Survey of Ohio, 1905.
9. Lane, Communication of Nov. 11, 1907, to George W. Stose, Editor of Maps, U. S. Geological Survey.
10. Geological Survey of Michigan, vol. V., pt. II, 1895, p. 20.
11. Communication of Apr. 20, 1903 to Prof. Charles S. Prosser. In his latest discussion of this sandstone Lane uses the term "Berea Grit" (Michigan Geological Report for 1908, p. 74) for the sandstone, regarding it as the base of the Carboniferous and the equivalent of the Catskill of New York.

of the formation is marked by a belt of brackish to salty wells, some of them so heavily charged as to be unfit for use. The records of the character of the rock encountered by the farmers, in the comparatively few wells available, are so incomplete and often conflicting that the stratum can be traced only with difficulty. It lies in Wayne County under a cover of 50 to 100 feet of drift and is seldom penetrated or entered to any considerable depth. In the Ann Arbor Court House well, Rominger identified 92 feet of coarse, gray sandstone, charged with brine, as the correlative of the Berea and suggested that the overlying 28 feet of black, bituminous shale would correspond with the shales found in Ohio above the Berea.[12] These have been known variously as the Waverly black slate, Berea shale and Sunbury shale.[13] In the Campus well. Lane includes under "Berea sandstone" 15 feet of fine, gray sandstone and 115 feet of more or less sandy shale, above which are recognized 45 feet of dark shale with the suggestion that this may represent the Sunbury. The not infrequent references to black shale and "slate" in the townships of Canton, Nankin, Livonia and Redford suggest strongly that this stratum extends across Wayne County also, although it is difficult to distinguish between it and the Antrim shale, beneath the Berea. The record of the deep well at Pontiac, 11 miles north of the Oakland—Wayne county line, shows the rather surprising thickness of 273 feet (depth 535 to 808 feet), for the Berea sandstone,[14] above which lie 35 feet of "dark brown argillaceous shale," constituting the base of the Coldwater and the probable correlative of the Sunbury.

DEVONIAN SYSTEM.

Antrim shale. Beneath the Berea sandstone in southeastern Michigan, there lies a characteristic black shale formation, 150 to 275 feet in thickness,[15] which has been variously designated in the Michigan and Ohio Survey reports. In the Houghton survey, it was referred to as the "black strata", "black bituminous shale", "black aluminous slate". By Winchell, it constituted the main member of his "Huron Group" and was regarded as the correlative of the Genesee shale of New York. Newberry in 1871 applied the name "Huron shale" to the formation which up to that time in Ohio had been known as the "black slate," and this name is still retained in the latest Ohio bulletins. Rominger described the for-

12. Geological Survey of Michigan, vol. III, pt. I, 1876, p. 92.
13. Hicks, The Waverly Group in Central Ohio: American Journal of Science, 3rd series, vol. XVI, 1878, p. 216.
14. Geological Survey of Michigan, vol. V, pt. II, 1895, pl. XLVII.
15. In the Campus well, Ann Arbor, 160 ft. (Lane). Court House well, Ann Arbor, 275 ft. (Rominger). Pontiac deep well, 157 ft. (Wright). Adrian well, 221 ft. (Lane).

mation under the name "black shales of Ohio." Lane applied the name "St. Clair shales" in 1893[16] and, finding this name preoccupied for a Silurian limestone in Arkansas, in 1901 changed the name to "Antrim shales" from their typical exposure in that county.[17] The early names are suggestive of the black, bituminous character of the shale, so much organic matter often being present as to permit of their burning and to their being mistaken for coal.[18] An analysis of Antrim shale of Charlevoix County was made to test its possible fuel value and is given by Ries.[19] Although they do not or-

TABLE XXXIII.—ANALYSIS OF ANTRIM SHALE, CHARLEVOIX COUNTY.

(Analyst W. H. Johnson.)

Volatile matter	17.96
Fixed carbon	6.49
Ash	75.55
Total	100.00
Analysis of ash.	
Silica, (SiO_2)	70.54
Alumina, (Al_2O_3)	15.33
Ferric oxide, (Fe_2O_3)	5.31
Calcium oxide, (CaO)	2.38
Magnesium oxide, (MgO)	.78
Alkalies, etc., by difference	5.66
Total	100.00

dinarily support combustion, beach fires on the shore of Sulphur Island, Thunder Bay, are said to have burned for many months. Upon the shores of this island these shales are black, very fissile, crisp and sharp, approaching slate when unweathered. They are finely laminated and very evenly bedded. Exposed to the weather they assume a gray, or rusty brown color, from the oxidation of the iron. Crystals of pyrite and nodules of marcasite are of common occurrence in these shales, which upon suffering decomposition stain the shales with iron oxides and sulphur and impregnate the percolating waters. Spherical to ellipsoidal calcareous concretions, varying in size from an inch to six feet in diameter, are found embedded in the shale. Toward the center of these there sometimes occur fragments of organic remains and crystals of calcite and siderite. It was from such concretions in this same formation that the remarkable fish remains of Ohio were obtained by Rev. H. Hertzer and later described by Newberry (see reference below, page 157). Concretions similar to those in Mich-

16. Michigan Geological Survey, Report for 1891 and 1892; 1893, p. 66. See also vol. V' pt. II, 1895, p. 21.
17. Michigan Miner, Sept. 1, 1901. Also Report of the State Board of Geological Survey for the year 1901; 1902, p. 209.
18. Lane, Deep Wells and Prospects for Oil and Gas: Report of the State Board of Geological Survey for the year 1901; 1902, p. 212.
19. Ries, Clays and Shales of Michigan: Geological Survey of Michigan, vol. VIII, pt. I, 1900, p. 47.

igan have been described by Daly from Kettle Point, Ontario, where the same formation is exposed by the waves. This author calls attention to the deformation of the shale on all sides of each concretion and concludes that they were formed *in situ,* that they antedate the period of joint development and final consolidation of the shale and that the deformation resulted from the change in volume when the original calcium bicarbonate was converted into the monocarbonate.[20]

Not infrequently these shales appear to be impregnated with oil, have a strong bituminous odor and have given off considerable quantities of "natural gas." When allowed to accumulate under a suitable cover of clay, "pockets" of such gas, under very great pressure, have occasionally been struck in well boring. It is likely that by entering the bed sufficiently more or less gas could always be procured which could be utilized in the homes situated over the formation, but the expectation can not be realized that any considerable flow can be long maintained. New wells could be drilled, or the former ones deepened when the supply ceased. The bituminous constituent in the shale is due very largely to the presence of enormous numbers of minute disc-like bodies, with relatively thick carbonaceous walls. These were discovered by Dawson in the shales of Kettle Point, Lake Huron, and described by him in 1871, under the name *Sporangites Huronensis.*[21] Remains of *Calamites* and *Lepidodendron* were found in association by Dawson and he regarded them as spore cases belonging to the latter type of tree. From material derived from Brazil two additional species of *Sporangites* were described in 1883 (*S. Braziliensis* and *S. bilobatus*) and the similarity noted to the macrospores of the floating fern of European rivers, *Salvinia natans.*[22] The generic name *Protosalvinia* was suggested to cover the former *Sporangites* which he then regarded as macrospores with their envelopes lost. Clarke found them abundant also in the Marcellus shale of Ontario County, New York,[23] associated with immense numbers of still smaller sub-spherical bodies which he regarded as the *microspores.* Newberry, as early as 1873, had called attention to the difficulty of conceiving of such widespread shallow water conditions, capable of furnishing the necessary shore vegetation, but with

20. Daly, The Calcareous Concretions of Kettle Point, Lambton County, Ontario: Journal of Geology, vol. VIII, No. 2, p. 135. See also Newberry, Geological Survey of Ohio, vol. I, pt. I, 1873, p. 155.
21. American Journal of Science, 3rd series, vol. I, 1871, p. 256. See also Orton, A Source of the Bituminous Matter in the Devonian and Sub-Carboniferous Black Shales of Ohio: same journal, 3rd series, vol. XXIV, 1882, p. 171.
22. Dawson, On Rhizocarps in the Palaeozoic Period: Proceedings of the American Association for the Advancement of Science, 1883, p. 260.
23. Clarke, On Devonian Spores: American Journal of Science, 3rd series, vol. XXIX, 1885, p. 284.

the evidence of the proximity of the shore so completely wanting.[24] He concluded his discussion as follows: "Waiting the demonstrative solution of the problem, which patient and exhaustive study will doubtless sometime furnish, I offer, as a possible explanation of the peculiar features of the Huron shale, the suggestion that its carbon was derived from vegetation which lined the shores and covered the surface of a quiet and almost land-surrounded sea."

Aside from the fossils above referred to, which are not serviceable for correlating these shales with the New York series, there is little help that palaeontology can render. They rest upon undoubted Hamilton and are lithologically identical with the Genesee shales of central New York. They have been so referred by Winchell, Rominger, Newberry, Whiteaves and Orton. Lane made the Antrim the equivalent of both the Bedford and Ohio shales in Ohio and these he correlated with the Tully, Genesee and Portage of New York. In the report of 1908, Lane places the shales "somewhat later" than the Genesee, based upon the evidence of a Naples fauna at the base, bringing them into the Portage of the New York scale.

Although known that the general dip of the stratum is toward the northwest, sufficient data are not available for the determination of the amount of such dip. Since these shales so nearly conform with those underlying, it may be assumed that the dip is practically the same as that of the Dundee and Upper Monroe and amounts to about 25 feet to the mile. Comparing the Ann Arbor Campus well with that at Pontiac, it is noted that the base of the Antrim at the latter place is 231 feet lower than at Ann Arbor giving an average drop in the 34 miles of about 7 feet to the mile, towards the northeast. In almost the opposite direction and in approximately the same distance, Ann Arbor to Adrian, the drop is 195 feet, or about 5¾ feet to the mile. Measured upon the top of the Antrim, or what is the same thing, the base of the Berea, at Ann Arbor, the formation is 134 feet higher than at Adrian and 234 feet higher than at Pontiac. This indicates the existence of a great arch in these strata, what is known in geology as an anticlinal fold, which might have been reasonably expected to have yielded gas or oil. The sandstone could have served as a suitable reservoir, the gas or oil under pressure displacing the brines and the overlying impervious shale acting as an ideal cover to prevent the escape to the surface. In explanation of why no considerable quantities of these desired commodities were struck

24. Geological Survey of Ohio, vol. I, pt. 1, 1873, p. 156.

in either the Ann Arbor, or Ypsilanti wells, attention may be drawn to the fact that the longitudinal crest of this broad fold is tilted downward toward the northwest and this may have allowed the gas and oil that were slowly distilled from the Antrim shales to work their way upward and southeastward until a means of escape to the surface was found. In attempting to locate these shales upon the geological map, help is furnished by the records of gas in the wells and by the amount of drift cover. The greatest de-depressions in the rock surface seem to correspond with the belt of Antrim shales, as though it had suffered greater glacial, or preglacial erosion, than the limestones beneath or the sandstones immediately above.

Traverse group. The next member of the Devonian system, as we descend in the geological scale, is the *Traverse*, originally described by Winchell as the "Hamilton group" in his First Biennial Report (1861, page 69), and subsequently as the "Little Traverse." This latter name was shortened to *Traverse* in 1895 by Lane[25] by which it is still known in the state reports. The formation was quite fully described by Rominger[26] under the name "Hamilton group" and its fossil contents carefully studied. With no outcrops in the southeastern part of the state he did not recognize its presence in the well records and denied its existence. In northern Ohio, Newberry identified some 15 to 20 feet of highly fossiliferous blue shale with the Hamilton, which formation is now regarded as the "Olentangy shale" of N. H. Winchell. In western Ontario, the same formation is readily recognized in outcrop and well sections, showing a thickness of 225 to 350 feet, and, as in Michigan, consisting of alternating layers of limestone and shale. During the last decade a very complete study of the Traverse has been made by Grabau, his paper upon the "Stratigraphy of the Traverse Group of Michigan" appearing in 1902.[27] These and subsequent studies were made upon the numerous exposures in the eastern part of the peninsula, in the Alpena region and upon those on the opposite side of the state in the Traverse Bay region.

Lithologically considered the Traverse Group of Michigan and western Ontario is transitional between the underlying Dundee limestone formation and the overlying Antrim shale, in that it consists of alternating layers of limestone and bluish, calcareous shale, often referred to in the well records as "soapstone." In the Alpena and Traverse regions, the thickness is believed to be about

25. Geological Survey of Michigan, vol. V, pt. II, 1895, p. 24.
26. Geological Survey of Michigan, vol. III, pt. I, 1876, pp. 38 to 63.
27. Report of the State Board of Geological Survey of Michigan, for the year 1901. pp. 163 to 210.

600 feet, diminishing to near 300 feet in the St. Clair River region and to less than 200 feet in the southeastern corner of the state. In the Campus well at Ann Arbor, Lane refers 65 feet of "gray, calcareous shale" to this formation and it seems probable that the last 70 feet of "bluish, cherty limestone" in the Court House well may also be so referred. The deep well at Pontiac gives the following series of Traverse strata:

TABLE XXXIV.—TRAVERSE STRATA, PONTIAC WELL.

Dark drab, coarse-grained, argillaceous limestone	25 feet.
Light drab, fine-grained limestone; 2% insoluble residue	10 feet.
Light drab, greyish white limestone; 8% insoluble residue	7 feet.
Light grey limestone; 20% insoluble residue	8 feet.
Sandy limestone, dark drab; 20% insoluble residue	35 feet.
Argillaceous limestone; 10% insoluble residue	15 feet.
Light blue, calcareous clay; 90% insoluble residue	50 feet.
	150 feet.

In this section there occur 100 feet of rather impure limestone and 50 feet of calcareous clay, which throw light upon the Wayne County records and show what may be expected in the case of new wells penetrating the formation. In the case of the Milan deep well (14 miles south-southeast from Ann Arbor) the Traverse series is as follows:

TABLE XXXV.—TRAVERSE STRATA, MILAN WELL.

Cherty limestone	30 feet.
Blue shale	45 feet.
Blue, shaly limestone	65 feet.
Limestone	28 feet.
	168 feet.

Although some of the limestone strata pass into dolomite, with the introduction of magnesium, others are of high grade, as indicated by the following table of analyses from the Alpena region.[28]

TABLE XXXVI.—ANALYSES OF TRAVERSE LIMESTONE, ALPENA PORTLAND CEMENT COMPANY.

Calcium carbonate ($CaCO_3$)	89.10% to 98.37%
Magnesium carbonate ($MgCO_3$)	.92% to 8.67%
Silica (SiO_2)	.33% to 1.77%
Iron oxide (Fe_2O_3) and alumina (Al_2O_3)	.13% to 1.21%

The clays and shales of the same formation in the Alpena region show the following composition:

28. For fuller data see Grabau's paper, Report of the State Board of Geological Survey of Michigan for the year 1901; 1902, p. 181.

TABLE XXXVII.—ANALYSES OF TRAVERSE SHALES AND CLAYS, NEAR ALPENA.

	(1)	(2)	(3)
Silica (SiO_2)	55.80	54.46	55.68
Alumina (Al_2O_3)	20.93	17.26	20.68
Ferric oxide (Fe_2O_3)	5.11	4.66	
Calcium oxide (CaO)	1.98	6.60	9.69
Magnesium oxide (MgO)	1.23	2.82	2.35
Alkalies (K_2O, Na_2O)	5.55	14.20	3.60
Loss by ignition	7.78		.....
	98.38	100.00	92.00

(1) Dock street clay; 5 feet below surface.
(2) Warner brick yard, blue shale.
(3) Fletcher dam, Thunder Bay River, blue shale.

From the same locality, Ries (*loc. cit.*, foot note 19) gives an analysis of a shale outcropping to the north of Alpena, belonging to the Alpena Portland Cement Company.

TABLE XXXVIII.—ANALYSIS OF TRAVERSE SHALE NORTH OF ALPENA.

Silica (SiO_2)	61.09%
Alumina (Al_2O_3)	19.19
Ferric oxide (Fe_2O_3)	6.78
Calcium oxide (CaO)	2.51
Magnesium oxide (MgO)	.65
Potassium oxide (K_2O)	1.80
Sodium oxide (Na_2O)	1.36
Sulphuric anhydride (SO_3)	1.42
Water (H_2O) and carbon dioxide (CO_2)	5.13
	99.93

As used by Lane, the Traverse Group of Michigan includes both the Hamilton and lower lying Marcellus of the New York series, and hence is the western equivalent of the Erian of Clarke and Schuchert. It carries an abundance of fossils which are often in splendid state of preservation and easily separated from the shales. In southeastern Michigan, these fossils are often found in the glacial gravels and fragments may be obtained in well drilling.[29] The formation forms a belt from two to five miles broad, extending northeast to southwest across the county of Wayne. It is covered by some 50 to 150 feet of drift and has approximately the same northwesterly dip as the overlying Antrim shale. The main body of Traverse shale is separated from the Antrim by the layers of limestone and is readily distinguished from it by its bluish color and soapy character when wet. The conditions favorable for the remarkable growth of marine vegetation that characterized the Antrim had not yet been established in the west during Traverse time. Highly mineralized water is sometimes met with from this formation but too impure to be utilized as a brine, in this respect differing from that of the Berea sandstone. The relatively small amount of organic matter preserved in the strata has given rise to very little or no gas and oil.

29. For descriptions and figures of Traverse fossils see vol. III, Geological Survey of Michigan, 1876, pt. II, Fossil Corals by Rominger.

Dundee limestone. Under a heavy burden of drift, the preceding geological formations are but imperfectly known in Wayne County. We come now to a series of strata which have been carefully studied in outcrop, were penetrated in the Oakwood salt shaft and of which we have numerous well records, based upon actual samples of the drillings. The first of these is the Dundee limestone, one of the first to be recognized in the state and utilized for building purposes and in the manufacture of lime. In every direction from southeastern Michigan, it extends persistently for great distances and underlies hundreds of thousands of square miles of the lake region, the Ohio and Mississippi basins. It represents the upper member of a group of strata found well exposed in the Helderberg Mountains of eastern New York, to which group the name "Helderberg" was given by Conrad, the early palæontologist of the New York Survey. Under the names "Helderberg series," or "Helderberg division," these strata were described in the Final Reports of the various districts prepared by Mather, Emmons, Vanuxem and Hall (1842-3). It was soon found that this and the other geographic names there used were entirely arbitrary and ill suited for group divisions until they had been subdivided upon the basis of their carefully studied fossil contents. In his review of these New York reports, Owen suggested a regrouping of the minor divisions and a renaming of the main divisions. Attracted by this work in the United States, the able French palæontologist M. Ed. de Verneuil made a season's study of the formations with a view to correlating them with those of Europe and suggested the grouping together of the lower strata of the Helderberg series, found to be of Silurian age, under the name "Lower Helderberg." This placed the upper members in the Devonian and suggested the use of the term "Upper Helderberg." In his translation and review of the paper of de Verneuil, Hall refers to the "upper limestone series of the Helderberg"[30] and in 1851 uses the term "Upper Helderberg series" to include the Corniferous limestone, Onondaga limestone, Schoharie grit and Caudagalli grit.[31] De Verneuil expressed the opinion that the Oriskany sandstone should also be included in the series as marking the base of the Devonian and, in this view, Hall promptly concurred (page 302). The French scientist also proposed to unite the Caudagalli and Schoharie grits and the Onondaga and Corniferous limestones. The Corniferous had been originally named by Eaton, "the Cor-

30. The American Journal of Science and Arts, second series, vol. VII, 1849, p. 230.
31. Report on the Geology of the Lake Superior Land District; Foster and Whitney, part II, 1851, p. 288.

nitiferous limestone," in allusion to its content of *hornstone,* or chert, and made to include both the Upper and Lower Helderberg formations.[32] The propriety of uniting the Corniferous and Onondaga limestones of the Upper Helderberg series, was early admitted because of their lithologic similarity, their content of hornstone and the close similarity in fossils. As early as 1841 Hall had traced the main limestones of the Upper and Lower Helderberg groups into the middle west and had observed the disappearance to the westward of many of the intermediate formations.[33] But C. C. Douglass, assistant upon the early Michigan survey, had already recognized the Corniferous equivalency of the limestone of Monguagon township and subdivided them as follows:[34]

Limerocks of Lake Erie.
- a. Corniferous (Dundee).
- b. Silicious limestones, passing into sand (Sylvania).
- c. Compact gray or blue limestone (Monroe).

The term Corniferous for this limestone formation was very generally used in the earlier reports of the Ontario, Michigan, Ohio and Indiana surveys; "Upper Helderberg" being sometimes substituted. In 1894, Hall proposed to revive the term *"Onondaga"* for this formation[35] and this term has come into general use in the recent geological literature. In Ohio, Prosser recognizes a double division—the Delaware and Columbus limestones.[36] Owing to the difficulty of establishing exact correlations across distant areas, especially where gaps occur in the series, Lane defined the *Dundee* in 1895, as "extending down from the bluish beds of the Hamilton (Traverse) so long as the formation continues to be limestone, stopping with the appearance of dolomite or of gypsiferous shales."[37] Although much better exposed near Trenton than at Dundee and on the Macon, this name had long been preoccupied, and the village of Sibley had not then come into existence. The base of the Dundee (Devonian) was thus intended to be placed at the top of the Monroe formation (Silurian), the uppermost strata of which are so generally dolomite. The discovery of the

32. Geological Nomenclature Exhibited in a Synopsis of North American Rocks and Detritus: The American Journal of Science and Arts, vol. XIII, 1828, p. 385.

33. Hall, Notes upon the Geology of the Western States: The American Journal of Science, vol. XLII, 1842, p. 51. See also Report on the Geology of the Lake Superior Land District, Foster and Whitney, pt. II, 1851, p. 307.

34. Fourth Annual Report of the State Geologist (Michigan), 1841, p. 109.

35. Thirteenth Annual Report of the State Geologist (New York) for the year 1893, vol. I, 1894, p. 207.

36. Revised Nomenclature of the Ohio Geological Formations: Geological Survey of Ohio, fourth series, Bulletin No. 7, 1905, p. 4.

37. Geological Survey of Michigan, vol. V, pt. II, 1895, p. 25. See also Annual Report for 1908, p. 70, in which the occurrence of magnesian beds is noted near Mackinaw City, near the base of the Dundee.

Anderdon limestone, of high grade and carrying *Devonian* fossils, embedded in the Upper Monroe[38] and that the superposed dolomite strata may be absent enables the Dundee to rest directly upon this Anderdon, or to be separated from it by a very thin stratum of sand. Such is the case at the Sibley quarry near Trenton and at the Anderdon quarry near Amberstburg, Essex County, Ontario, where the original definition of the base of the Dundee becomes inapplicable and the separation between it and the Anderdon can be made only upon a palæontological basis. As thus defined by Lane it was intended to cover the entire time of the Upper Helderberg; Oriskany to Corniferous, inclusive.[39].

As seen in southeastern Michigan and western Ontario, the Dundee is essentially a pure limestone formation with occasional nodules, seams and thin strata of chert, an impure variety of quartz. The limestone varies in color from light gray to drab, buff to yellow, in some cases merging into blue. The purer varieties show numerous cleavage faces of calcite, or crystallized lime carbonate, and are heavily charged with fossil fragments. The argillaceous ingredient, abundant in the Traverse limestones, is usually small in amount, generally less than one per cent but may run up to 6 or 7% in certain beds. The iron content is also small but the silica and magnesium carbonate are subject to considerable variation. With dilute hydrochloric acid, the Dundee always gives vigorous effervescence by which it may be distinguished from the underlying Monroe dolomites. The beds not infrequently give a strong odor of oil and show drops of thick, black, bituminous matter in the small cavities. In Ontario and near Port Huron, the formation yields oil and gas where the structural conditions have been favorable.[40] It is also the source of a highly mineralized water, too impure for salt manufacture but valuable for medicinal and chemical uses. The composition of such a "mother liquor" from a deep well[41] at Port Huron is shown in the following analysis. The well is 750 feet deep and enters the Dundee 100 feet.

38. Grabau and Sherzer, The Monroe Formation of Southern Michigan and Adjoining Regions: Michigan Geological and Biological Survey, Geological Series I, 1910, p. 42.
39. Geological Survey of Michigan, vol. VII, pt. I, 1900, foot note, p. 37.
40. Gordon, The Port Huron Oil Field: Geological Survey of Michigan, Report for the year 1901; 1902, p. 269.
41. Annual Report for the year 1903; 1905, p. 109.

TABLE XXXIX.—ANALYSIS OF DUNDEE MINERAL WATER. "DEEP SPRINGS MINERAL WATER," PORT HURON, MICHIGAN.

(Analysts Dr. E. Ristenpart and Prof. R. C. Kedzie.)

	Parts per 1000.
Sodium chloride (NaCl)	66.6832
Potassium chloride (KCl)	2.8181
Ammonium chloride (NH_4Cl)	0.1431
Calcium chloride ($CaCl_2$)	5.2492
Magnesium chloride ($MgCl_2$)	6.7846
Magnesium bromide ($MgBr_2$)	0.0488
Magnesium iodide (MgI_2)	0.0003
Calcium bicarbonate $Ca(HCO_3)_2$	1.7600
Iron bicarbonate $Fe(HCO_3)_2$	0.0140
Calcium sulphate ($CaSO_4$)	3.7721
Sodium hyposulphite ($Na_2S_2O_4$)	0.0177
Sodium hydrosulphate (Na_2SO_4)	0.0136
Sodium carbonate (Na_2CO_3)	......
Lithium chloride (LiCl)	......
Alumina (Al_2O_3)	0.0033
Silica (SiO_2)	0.0085
Sulphuretted hydrogen gas (H_2S)	0.3146
Carbonic acid gas (CO_2)	0.7147

Studies upon the various layers of the Dundee as exposed in the Sibley quarry, near Trenton, were begun by the writer 15 years ago (June 1896), when there were recognized for commercial purposes the following series of strata; which for convenience of reference were assigned letters.

TABLE XL.—STRATA OF THE SIBLEY QUARRY, NEAR TRENTON.

A. "6 foot top." Yellow, brown to gray; thin-bedded; very fossiliferous.
B. "7 foot limestone." Thin-bedded, gray to bluish.
C. "2 foot limestone." Compact, gray, rich in fossils.
D. "5 foot limestone." Compact, crystalline, bluish where unweathered.
E. "6 foot limestone." Compact, gray to blue, fossil fragments abundant.
F. "14 inch flint." Brittle, bluish gray chert, some fossils.
G. "6 foot limestone." Gray to bluish, more heavily bedded.
H. "2 foot flint." Very brittle impure chert, some fossils.
I. "9 foot limestone." Compact, heavily bedded, blue to gray.
J. "6 foot magnesian." Similar to I but oily and fewer fossils.
K. "8 foot limestone." Gray, thin-bedded, fossiliferous.
L. "12 foot lower magnesian." Light to dark gray, fossiliferous.
M. "7 foot silicious." Thin-bedded, firm, poor in fossils.

Aside from the splendid exposure of the Dundee strata now seen at the Sibley quarry, the only other known locality in southeastern Michigan lies some 27-28 miles to the southwest at Dundee and the mouth of the Macon.[42] Four separate beds may be recognized at the Christiancy quarry, the second and third of which are separated by a thin stratum of chert, which from its fossil contents agrees with that designated "Bed F" in the Sibley quarry. If this correlation is correct, and there is much opportunity for uncertainty, the "2 foot flint" has disappeared and the four Macon beds exposed represents beds D, E, G and I of the Sibley quarry. Lithologically the beds seem to correspond, their combined thickness is 21 to 22 feet on the Macon and 26 feet at the Sibley quarry, and they seem to lie at about the same horizon, measured from the top of the dolomite (Flat Rock?). The base of "Bed I" at the

42. See author's Geological Report on Monroe County: **Geological Survey of Michigan.** vol. VII, pt. I, 1900, p. 75.

Sibley quarry is some 48 feet (including the Anderdon) above the dolomite while in the Christiancy quarry, the Nogard well record indicates that the base of the lowest stratum there is about 38 feet above the corresponding horizon. These variations in the thickness of the strata at these two localities harmonize with the apparent increase in the thickness of the entire formation to the northward. In actual elevation, the Sibley bed is about 18 feet lower, this representing the drop in the direction of the strike. The following analyses will be of interest for comparison with those of the Sibley and Anderdon limestones.

TABLE XLI.—ANALYSES OF DUNDEE LIMESTONE, CHRISTIANCY QUARRY.

(Analyst G. A. Kirchmeier.)

	Upper.	Second.	Third.	Lowest.
Calcium carbonate ($CaCO_3$)	90.80%	86.80%	77.60%	95.00%
Magnesium carbonate (MgCO*)	6.87	11.60	17.41	3.86
Silica (SiO_2)	0.48	1.10	2.78	0.81
Iron (Fe_2O_3?)	0.16	0.12	0.56	0.41
Organic matter	1.69	......	1.63	......
Difference	0.00	0.38	0.02	—0.08
	100.00	100.00	100.00	100.00

In a brief report upon the limestone of the Anderdon quarry,[43] Rev. Nattress gives the following average composition of certain of the richer beds, the analyses having been made by the Solvay Process Company of Detroit. It seems very probable that the samples covered both the Dundee and Anderdon formations, the

TABLE XLII.—AVERAGE COMPOSITION OF DUNDEE BEDS, ANDERDON QUARRY.

(Laboratory Solvay Process Co.)

Calcium carbonate ($CaCO_3$)	97.50%
Magnesium carbonate ($MgCO_3$)	1.50
Calcium sulphate ($CaSO_4$)	0.03
Silica (SiO_2)	0.80
Ferric oxide (Fe_2O_3) and Alumina (Al_2O_3)	0.09

latter of which had not yet been recognized and separated from the former. In the case of the former, recent determinations of the lime carbonate ingredient alone shows quite a wide range in amount, depending upon the presence mainly of magnesium carbonate and silica. The 76 analyses supplied by Rev. Nattress give an average of 62.49% and an extreme range of 40.34% to 95.26%. The samples were taken from drill cores through the beds believed to represent the basal layers of the Dundee, just above the Anderdon, which is still richer in lime carbonate (see Pl. XXIII for these beds now exposed in the quarry).

43. The Limestones of Ontario: Report of the Bureau of Mines, 1904, pt. II, p. 41.

In the summer of 1905 two drill cores were removed from the eastern and western sides of the Sibley quarry for the purpose of discovering the nature and thickness of the underlying beds. "No. 2," farthest west, started upon "Bed I," elevation about 583 feet above sea level, and extended to a depth of 83 feet. Through the kindness of Mr. Sundstrom, the writer was permitted to study these cores and was given the following set of analyses, which, taken in connection with the series of strata in the quarry, bring out admirably the essential nature of this economically important formation.

TABLE XLIII.—ANALYSES OF DRILL CORES, PROSPECT HOLE NO. 2, SIBLEY QUARRY.

(Laboratory Church and Co.)

Sample.	Depth.	Elevation.	$CaCO_3$	$MgCO_3$	SiO_2	Difference.	Remarks.
1........	5	578	87.63	8.72	1.98	1.67	Bed I.
2........	10	573	87.26	9.02	1.90	1.82	Bed J.
3........	16	567	83.99	11.56	2.78	1.67	Bed K?
4........	20	563	81.08	14.63	2.39	1.89	Bed K.
5........	25	558	93.26	4.82	0.73	1.19	Fossils.
6........	27	556	81.81	14.02	2.21	1.96	
7........	33	550	75.99	15.13	8.16	0.72	
8........	35	548	82.72	9.06	7.24	0.99	
9........	40	543	92.54	4.17	2.63	0.66	Base of Dundee.
10........	42	541	87.79	2.49	9.50	0.22	Anderdon.
11........	45	538	79.99	15.55	2.89	1.57	"
12........	48	535	87.08	7.91	4.95	0.06	"
13........	53	530	68.36	23.64	1.50	6.50	"
14........	55	528	70.54	23.49	0.96	5.01	"
15........	58	525	59.99	35.70	0.54	3.76	Flat Rock?
16........	62	521	64.72	32.57	0.49	2.21	" "
17........	65	518	62.36	33.34	0.29	4.01	" "
18........	70	513	59.45	37.00	0.68	2.87	" "
19........	78	505	54.27	43.04	0.22	2.54	" "
20........	80	503	59.15	37.88	1.05	1.92	" "
21........	83	500	58.09	40.04	0.31	0.56	" "

The "differences" consisted mainly of alumina, iron oxide, and organic matter and were not determined.

In August, 1907, Prof. A. W. Grabau examined these cores with the writer and was able to recognize the Anderdon character of the fossils seen in the cores from depth (Hole No. 2) 46.5 feet to about 51 feet. From a depth of 41 to 42 feet, there occurs a light brown limerock in which are thickly embedded quantities of fine, rounded, pure white, quartz granules, not to be distinguished from those derived from the Sylvania. At what appears to be the same horizon in the Anderdon quarry, upon the opposite side of Detroit River, Rev. Thomas Nattress, found a few inches of sand, or an incoherent sandstone. This occurrence is of interest since it marks the horizon of the Oriskany sandstone of the New York series

and the base of the Dundee. It probably resulted from transportation of Sylvania sand by the wind during a land interval between the Silurian and Devonian. In the table of analyses above given, the 15 to 16 feet (elevation 541 to 525) of limestone lying just beneath the sandy stratum are to be referred to the Anderdon. Beneath this lies some 25 feet of rock approaching normal dolomite in its composition and presumably representing the Flat Rock formation yet to be described. The strata of the Anderdon quarry have been made the subject of study for a number of years by Rev. Nattress and reported upon from time to time.[44] During the past summer and fall (1911), he has conducted a series of investigations for the Solvay Process Company in the district immediately to the west of the Sibley quarry.

The total thickness of the Dundee formation at the Sibley quarry appears to be about 90 to 100 feet where it has been pushed up to form a knoll, across which the earliest ice sheet moved with considerable vigor. How much was removed by glacial, or other agencies we may only surmise by ascertaining the total thickness at neighboring localities. At the Oakwood salt shaft the Dundee was found to have a thickness of 63 feet, but here again we have but a partial record, since it lies next to the drift cover of 83 feet. In Ohio, the maximum thickness of the formation is given as 100 feet, which thickness it retains for a few miles into Michigan. In the Adrian well record the separation of the Dundee and Monroe was not made but at Britton, Lenawee County, there were 100 feet of "white or brownish crinoidal limestone with water and traces of oil and gas," which are referred by Lane to the Dundee. At Milan, Monroe County, there occur 97 feet of the same formation. In the next dozen miles to the northward a rapid thickening seems to take place as indicated by the Ann Arbor and Ypsilanti records, the Campus well giving 185 feet and the Cornwell well at least 200 feet referable to this formation. The Pontiac and Royal Oak records, unfortunately, are not complete enough to be of service in this connection. At Petrolea, Ontario, the thickness is about 200 feet, according to the Canadian records. Judging from these records in the surrounding districts, the Dundee in Wayne County would have to be assigned an original thickness of about 100 feet, in the southwestern corner, to about 200 feet along

44. The Corniferous Exposure in Anderdon: Eleventh Report of the Bureau of Mines (Ontario), 1902, p. 123.
The Limestones of Ontario: Report of the Bureau of Mines, 1904, pt. II, p. 41. See also papers in the annual reports of the Michigan Academy of Science:
The Contour of the Sylvania Sandrock and related strata in the Detroit River Area: 12th Report, 1910, p. 47.
The Extent of the Anderdon Beds of Essex County, Ontario, and their place in the Geologic Column: 13th Report, 1911, p. 87.

the northern border. In the numerous wells along Detroit River, the records are either incomplete, or penetrate only a portion of the formation. The Stroh Brewery well, on Gratiot Avenue, Detroit, shows 400 feet of "limestone," from the base of the Traverse to the top of the Sylvania, two very well defined horizons. This includes the Dundee and Upper Monroe, the latter of which in the Oakwood salt shaft has a thickness of 274 feet, leaving some 126 feet for the Dundee.

Between the outcrop at the mouth of the Macon, in Monroe County, and that at Sibley, the drift cover is relatively light, but still amounting to 30 to 80 feet, hopelessly covering a rock for which there is now great demand. Towards the north, this burden of drift increases until it exceeds 100 feet. The breadth of the outcrop, *beneath this cover,* ranges from four to twelve miles (see Pl. XXV) and the strike of the formation is toward northeast as it enters the county, curving around to the eastward and apparently shifting the direction of dip from northwest around towards the north. At the Sibley quarry, the rock strata have been disturbed and both the strike, amount and direction of dip are abnormal. At the time of their study by the writer in 1896 the dip as carefully determined by transit was found to be 5° south of west and equal to 4.4 feet per hundred, measured along the top of "Bed J." The surface of "Bed I" showed a drop per hundred feet of 3.9 feet. In the old Christiancy quarry upon the Macon, the former foreman, Mr. T. J. Brandt estimated the direction of dip as W. NW. and the amount as about .45 feet to the 100 feet. In the Dundee quarry it was found to be approximately 2.25 feet to the hundred. The average dip of the strata for the county can be determined only by an examination of the well records for which we have reliable data, the base of the Dundee in the salt shaft being known to have been reached at a depth of 146 feet (elevation of mouth 575.2 feet above sea level) or at an elevation of 429 feet. In the Campus well at Ann Arbor the base of the Dundee is 50 feet *below* sea level, giving a drop in the 32.5 miles from Detroit to Ann Arbor of 479 feet, or an average of 14.74 feet to the mile. This is in a direction, however, almost due west and hence does not indicate the real dip of the beds. From Detroit towards Royal Oak, or Pontiac, would more nearly furnish the desired data but, unfortunately, the separation of the Dundee from the Monroe can not be made in the well records at these two places. Dropping to the level of the top of the Sylvania, the dip from Detroit to Ann Arbor is found to be 15.7 feet to the mile. In the

Pontiac well, N. NW. from Detroit, there occurs an arenaceous limestone which probably marks the horizon of the Sylvania. If we make this assumption, the dip in this direction is about 21.2 feet to the mile. The top of the Sylvania is much better defined in the Royal Oak deep well (SW. ¼ sec. 19), at a depth of 836 feet, but unfortunately the elevation of the mouth of the well is not given with the record. If we take this from the topographic map as about 678 feet above sea level, then we have an average dip indicated in almost due north direction of about 22 feet to the mile. Until more reliable data are at hand we may assume that the average dip is not far from 25 feet to the mile and in a direction north-northwest.

In connection with the Antrim shales, attention was called to an anticlinal fold with its crest near Ann Arbor and the economic importance of such structural features was there pointed out. When the Dundee is similarly examined it is found that the base of this formation at Ann Arbor (—50 feet) is *lower* than at Milan (+290 feet), or at Royal Oak (about sea level), indicating the presence of a synclinal trough in the surface of the Upper Monroe. In private conversation Prof. I. C. Russell called attention to the fact that the production of the great basin-like depression over central Michigan must have produced a series of such wrinkles in the strata radiating from the center. The suggestion has value in the search for oil and gas in that if a series of test wells is being put down their direction should be *tangential* to the basin; i.e., northeast to southwest in southeastern Michigan. If a successful well is once reached a *radial* position for new ones is to be recommended with reference to the central basin; i.e., so placed that the line will point toward the center of the basin.

A full suite of fossils was collected from the Sibley strata and these have been made the subject of study by Prof A. W. Grabau, whose preliminary report upon the same is found in Chapter X. Dr. Carl Rominger had also collected extensively from the same beds and his lists are given in Vol. III, issued in 1876, with photographic views of the corals. Most of the strata are surprisingly rich in fossil forms, often proving to be a solid, coquina-like mass of shells, corals and crinoid joints. Even when the limestone appears quite compact, the weathered portions reveal more or less of this structure. The discussion of the conditions under which this material accumulated and resulted in the formation of limestone and chert will be found in the writer's report upon Monroe County.[45] It may be stated here simply that warm, open,

45. Geological Survey of Michigan, vol. VII, 1900, pt. I, p. 40.

shallow sea conditions prevailed, far enough removed from land to escape deposits of mud and sand. Floating vegetation, so abundant later, had not yet invaded the sea and the oil and gas were probably very largely of animal origin. The Michigan basin as far north as James Bay was covered by this epicontinental sea which communicated eastward with the Atlantic and southward with the Gulf of Mexico from which came a rich fauna of corals and brachiopods which gave rise to extensive reefs.

SILURIAN SYSTEM.

The establishment of this world-wide system dates back to 1839 and was made by Murchison as the result of his extended studies upon the formations of the region of Great Britain, formerly occupied by the ancient tribe of *Silures*.[46] Two main divisions were recognized, an Upper and a Lower Silurian (p. 265). Almost immediately, the system received recognition in this country by Conrad who endeavored to correlate the New York strata with their English equivalents upon the basis of fossil similarity.[47] Owing to the pronounced break between the upper and lower divisions, it was proposed in 1879 by Lapworth to recognize each division as a *system,* retaining *Silurian* for the upper and using *Ordovician* for the lower, the name derived as the other had been from an ancient tribe of Wales, the *Ordovices*.[48] This suggestion has been largely adopted in the recent English and American texts on geology and has much to commend it. In Wayne County, the Silurian System only has been completely penetrated by the wells and only the uppermost formations are to be seen in outcrop. The Ordovician is reached in the deeper wells in Wayne and Monroe counties and is seen in outcrop towards Ohio River.

Monroe formation. The formation to which this term is now applied has been known in the state reports under a variety of names, as an effort has been made to correlate its strata with those of the standard New York series. It has recently been made the subject of joint study by Prof. A. W. Grabau and the writer and described in a special report[49] to which those especially interested may be referred. Three main divisions are readily recognized; an upper and a lower set of dolomitic limestones, separated by a

46. The Silurian System, founded on Geological Researches in the Counties of Salop, Hereford, Radnor, etc., with descriptions of the Coal fields and overlying formations. R. J. Murchison, London, 1839.
47. On the Silurian System, with a Table of Strata and Characteristic Fossils: American Journal of Science, vol. 38, 1840, p. 86.
48. Lapworth, On the Tripartite Classification of the Lower Palaeozoic Rocks: The Geological Magazine, New Series, vol. VI, 1879, p. 13.
49. Grabau and Sherzer, The Monroe Formation of Southern Michigan and Adjoining Regions: Michigan Geological and Biological Survey, Publication 2, Geological Series 1, 1910.

stratum of incoherent sandrock known as the Sylvania. Only the upper member of the entire series is believed to extend into New York, where it makes up the lower portion of the original Helderberg division and constitutes a portion of that which was set off by De Verneuil as the "Lower Helderberg." In his western trip, taken in 1841, for the purpose of correlating the strata of the middle states with those of New York, Hall referred certain limestones in the vicinity of Mackinac to the Onondaga Salt Group and the Waterlime.[50] The first recognition of Lower Helderberg strata in the Lake Erie region was made by Chapman in 1864, who suggested for it the name "Bertie dolomite."[51] The Waterlime equivalency of the Lake Erie dolomites was announced by Newberry and Winchell in 1871 and recognized, more or less generally, in the Ohio, Michigan and Ontario survey reports. In Ohio, the term "Lower Helderberg" was contracted to *Helderberg,* which was believed to be represented by the Waterlime alone with a thickness of 100 feet. Rominger in Michigan used the name "Helderberg Group" and extended its meaning to more nearly that of the early New York reports, making it include both the Dundee and Monroe and not endeavoring to separate them upon his geological map. The sandrock stratum (Sylvania) was supposed to separate the two members and had been regarded generally as the correlative of the Oriskany. In 1873 it was noted by N. H. Winchell that this formation is *embedded* in the dolomites, instead of being at the top of the series, which observation was later confirmed by Orton in Ohio and the writer in Michigan.[52] Because of its exposure and utilization near the village of Sylvania, Ohio, Orton suggested this name for the formation (*loc. cit.*, p. 18). It must be regarded, of course, as of the same geological age as that of the dolomites themselves.

Owing to the difficulty of separating this entire series, upon which rests the Dundee, from the underlying Salina formation, it was proposed in 1893 by Lane to use the name "Monroe beds" for the series intervening between the base of the Dundee and the top of the Niagara.[53] The formation was not defined until 1895, "as extending from the limestones of the overlying Dundee down to the lowest gypsiferous beds, and to consist mainly of buff dolomites

50. Geology of New York, pt. IV, 1843, p. 512. Also Report on the Geology of the Lake Superior Land District, Foster and Whitney, pt. II, 1851, pp. 162-3.
51. A Popular and Practical Exposition of the Minerals and Geology of Canada, E. J. Chapman, 1864, p. 190.
52. Winchell, Geological Survey of Ohio, vol. I, 1873, p. 603.
Orton, Geological Survey of Ohio, vol. VI, 1888, p. 18. Also vol. VII, 1893, p. 17.
Sherzer, Geological Survey of Michigan, vol. VII, pt. I, 1900, p. 60.
53. Report of the State Board of the Geological Survey of Michigan for 1891 and 1892; 1893, p. 66. This name was selected because of the excellent exposures of the strata in Monroe County.

and of calcareous and argillaceous marls, associated with anhydrite and rock salt."[54] Based upon the evidence of the well records the thickness was placed at 1200 feet and the beds were believed to have been deposited in an excessively salt interior sea, extending from New York to eastern Wisconsin, exposed to a hot sun and receiving little accession of fresh water from rivers. Shallow water conditions prevailed in places, particularly in Ohio, where there was a great bar, reef or flat, permitting the formation of ripple-marks and mud-cracks. In southeastern Michigan, three periods of dessication were recognized, the first and greatest of which gave rise to the heavy beds of rock salt, aggregating in thickness some 600 feet; the second preceded the formation of the Sylvania (Middle Monroe) and resulted in the formation of gypsums, or salty dolomites, and occasional beds of oölite. The third period of dessication occurred during the deposition of the Upper Monroe series. The name "Monroe Group" for this series was approved in May, 1903, by the Committee on Geological Names of the United States Geological Survey.

In 1908 Grabau proposed to subdivide the Monroe into an upper, middle and lower division and to remove from it the Salina formation,[55] which in the New York series had been known as the Onondaga Salt Group. In a joint paper by Grabau, Lane, Prosser and Sherzer, presented at the same time before the Albuquerque meeting of the Geological Society of America and the Chicago meeting of the American Association for the Advancement of Science, this subdivision and restriction of the Monroe was recognized.[56] The upper and lower divisions were further subdivided as shown in the accompanying table, with the approximate thickness of each member.

TABLE XLIV.—THE MONROE FORMATION OF MICHIGAN.

Dundee Formation.

Monroe Formation.		disconformity.	
	C. Upper Monroe or Detroit River Series.	Lucas dolomite........	200 ft. +
		Amherstburg dolomite..	20–50
		Anderdon limestone....	35–60
		Flat Rock dolomite.....	40–100
		disconformity.	
	B. Sylvania sandstone and dolomites...........................		30–300
		disconformity.	
	A. Lower Monroe or Bass Islands Series.	Raisin River dolomite...	200
		Put-in-Bay dolomite....	100
		Tymochtee shales.. ..	90
		Greenfield dolomite.....	100
		disconformity.	

Salina Formation.

54. Geological Survey of Michigan, vol. V, 1895, pt. II, p. 27.
55. Science, new series, vol. XXVII, 1908, p. 622.
56. Nomenclature and Subdivision of the Upper Siluric Strata of Michigan, Ohio, and Western New York: Bulletin of the Geological Society of America, vol. XIX, 1909, p. 556.

In the typical locality, the Upper Monroe, or Detroit River Series, shows a thickness of about 100 feet at Wyandotte, to 350 feet at Windsor, Ontario, including the series of dolomites and limestone that intervene between the base of the Dundee and the top of the Sylvania sandstone. Extensive erosion of these beds seems to have taken place in the present vicinity of the lower Detroit River region previous to the deposition of the Dundee. The Middle Monroe, or Sylvania member, consists, in the main, of a pure, incoherent sandrock, not infrequently divided by a bed of silicious dolomite, sometimes, by two such beds. In the upper Detroit River region, the average thickness of this member is about 100 feet, but is found to be variable and to entirely disappear in some well sections. The thickness grows less to the southward and greater toward the northwest. The Lower Monroe, or Bass Islands Series (from the islands in the western end of Lake Erie), extends from the base of the Sylvania to the top of the Salina, which may be regarded in well records as the first bed of salt, or first heavy bed of gypsum. A comparison of the logs of adjacent wells, as for instance those of Wyandotte and Trenton, shows that some of the upper rock salt strata are replaced to the southward by deposits of gypsum. Without doubt, some of the strata lying above these salt and gypsum deposits are referable to the Salina and it was hoped that the record of the salt shaft at Oakwood would enable us to ascertain the thickness of these strata for that region. Unfortunately for this purpose, these beds proved unfossiliferous and with no structural break that could be observed it seems necessary to place the base of the Monroe at, or near the heavy salt or gypsum deposits. Thus limited, the Lower Monroe in the 17 wells of the Solvay Process Company, Delray, gives an average thickness of 360 feet and the entire Monroe formation of southeastern Michigan and western Ontario has a development ranging variously from 500 to 900 feet.

The best exposures, both natural and artificial, are to be found in Monroe County of each of the three main divisions of the formation. The Upper Monroe strata in Wayne County have been best seen in the quarry west of Gibraltar, now abandoned, and were formerly exposed in the shallow quarries on Stony Island and Grosse Isle. The Middle Monroe, or Sylvania member, may be seen in the pit of the American Silica Company, just east of Rockwood, where it was covered by some 15 to 20 feet of glacial clay. The Lower Monroe is not exposed in the county but a very good section and suites of specimens were obtained at the Oakwood salt shaft.

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Rev. Thomas Nattress has recently endeavored to show[57] that the dolomites which constitute the bed of Detroit River in the vicinity of Stony Island are of Lower Monroe age and that the Sylvania sandstone, or Middle Monroe, swings in a sharp, horseshoe shaped curve from the vicinity of Gibraltar, northward about the head of Grosse Isle and back to Bois Blanc Island, opposite Amherstburg; the respective exposures being upon "opposite sides of the *Cincinnati anticline,*" and with a possible distance across of but about three miles at the broadest place. The conception was that the Sylvania represents a shore deposit about this very narrow peninsula of early Monroe dolomite and the argument was based upon theoretic considerations of dip and strike and the supposed absence of the Sylvania in the lower Trenton channel of Detroit River. Against this view many objections may be urged; first of which is that the crest of the Cincinnati anticline lies some 25 to 30 miles to the eastward; that it is not a narrow ridge, having "little or nothing of the character of an anticlinal or arch. * * * * no roof-shaped arrangement of the strata whatever, * * * * but a nearly level tract," (Orton) that could not be set down in Detroit River and still leave room for the thick Sylvania deposit upon either side. Furthermore, the "Cincinnati anticline" was formed before any of these Detroit River strata came into existence and not between Lower and Middle Monroe time, as would have had to be the case if the above arrangement held. But, if not the "Cincinnati anticline," could there have been a similar, but younger wrinkle in these strata that would satisfactorily account for all the phenomena? The Sylvania formation at Rockwood is 75 feet thick, 90 and 180 feet thick at Trenton, 60 and 100 feet at Wyandotte; and, although growing thinner to the eastward, unless we assume that it possesses a very much greater dip than it, or any contiguous strata are known to have, there would not be room in the area assigned to have the formation describe such a curve about a ridge of dolomite (see Pl. XXV). Outcropping (beneath the drift) at the mouth of the Huron with a breadth of two to three miles, by the time the Sylvania reaches Trenton it has dropped to a depth of 285 feet, while at Wyandotte its average depth is 213 feet, at both of which places we should expect to find the formation at, or very near the base of the drift. Furthermore, we should expect to find some trace of the formation in the channel bed passing either side of Grosse Isle, but nothing of the kind has ever been noted. Near the southern end of Bois Blanc Island a

57. The Contour of the Sylvania Sandrock and Related Strata in the Detroit River Area: Twelfth Report of the Michigan Academy of Science, 1910, p. 47.

well belonging to Capt. Walter Campbell was abandoned because of the great quantity of this sand pumped from it. At Elliott's Point, upon the Canadian mainland, there are reported 44 feet of glacial clay, 25 feet of dolomite and then the Sylvania sandstone entered to a depth of 14 feet. At the adjoining farm to the north the depth to rock was 41 feet, with but a foot of "shale" overlying the Sylvania, which was reported as but 20 feet thick. Many reasons have been given for thinking that the Sylvania is not a shore deposit at all but a wind blown and wind deposited mass of sand, in which case it would sustain no such relation to the peninsular fold assumed by Nattress to have been dry land at the time of its formation. Its supposed absence from the bed of the river, where it has been assumed to cross to the southward of Celeron Island, where not still covered by till, may be readily accounted for by the action of the present, or early Detroit River, at one stage of which it flowed to a considerably lower level (560 feet above sea level). Furthermore, if the Sylvania is an aeolian deposit there is no reason to expect that it must be continuous from one point to another.

As to the Lower Monroe age of the dolomites of the Detroit River bed and adjacent islands, structural and stratigraphic relations can furnish only a very uncertain guide. If fossils were absent, we should be compelled to rely upon lithological characters and these all point to the Upper Monroe age of the strata exposed in the Livingstone Channel (Pl. XXIV). But, unlimited quantities of excellently preserved fossils, corals being especially abundant, are available and will continue to be until the tremendous pile of dump is removed from the river. A large box of such material was submitted to Prof. A. W. Grabau, during the summer of 1911, and he unhesitatingly pronounces the strata of Upper Monroe age (Lucas and Amherstburg), which means that the Sylvania underlies Grosse Isle. It should be noted that corals are entirely absent from the Lower Monroe of southeastern Michigan, but are so abundant in the Livingstone Channel region as to almost constitute a reef. In the case of the Swan well, at the southwestern corner of this island, the owner Judge Swan feels confident that the Sylvania was penetrated early in the drilling, the drill requiring very frequent sharpening. While the drilling was in progress by the West Virginia Drilling Company (St. Marys, West Virginia) the well was visited by Forest B. H. Brown for the State Survey. A depth of 785 feet had been reached (July, 1903) which gave 14 feet of clay, 300 feet of "limestone" and 70 + feet of sand. These

figures would give an elevation here of the surface of the Sylvania of 266 feet above sea level as compared with 290 and 300 feet at Trenton (Church and Co).

The fossils collected from the exposure at the southeastern corner of Celeron Island prove to be of *Lucas* age. Being so near the outcrop of the Sylvania, we should expect these beds to represent the Flat Rock division of the Upper Monroe, which was next in age to the Sylvania. This indicates that the Amherstburg, Anderdon and Flat Rock are either absent, or greatly attenuated at the mouth of Detroit River. Instead, then, of a dolomitic *ridge* of Lower Monroe age, as made out by Rev. Nattress, the evidence indicates that there existed a sandstone *basin* of Upper Monroe age in which the Detroit River beds were deposited.

In conformity with the overlying strata already described, the Monroe strata have a general northwesterly dip, swinging towards the north in the northern part of Wayne County, amounting probably to about 25 feet to the mile. In the lower Detroit River region, local disturbances have rendered the strike and dip irregular. At the Patrick quarry, south end of Grosse Isle, the strata were observed to dip S. 30° W. and to range in amount from 1½ to 2°. In the bed of Detroit River, opposite Stony Island, while the excavation for the Livingstone Channel was in progress, the average dip of the strata (seven determinations) was found to be S. 50° W. and to be equal to 1° 58′, or about 3.438 feet to the hundred. In the northern part of the area exposed, the strata showed a pronounced anticlinal fold, extending in an east-west direction across the river bed. The strata dip rather rapidly upon the southern slope of the fold, having been eroded along the plane of the river bed and indicate that the fold is one of considerable magnitude. Upon the eastern face of the channel wall, Rev. Nattress and the writer counted 32 strata which had an average thickness of 38.3 inches and a total maximum thickness of 102 feet. Bench marks in use in the construction of the channel and located upon the surface ledges have elevations of 566.16, 568.61 and 568.69 feet, above sea level, respectively. In the Anderdon quarry, upon the Canadian side to the eastward, the foreman, Patrick Hancock, in 1907, reported the dip of the beds as 6 feet to the hundred and about S. 23° W. in direction.

Recurring to the geological equivalency of the Monroe formation, it is believed by Grabau that only the three younger members of the Upper Monroe are represented in eastern New York by the Manlius, Rondout, Cobleskill and Rosendale formations. In west-

ern New York, the representation is still more meager, only the Amherstburg and Anderdon being correlated with the Akron and Bertie dolomites. A rather full discussion of these correlations and description of the fossils of the Monroe will be found in the bulletin cited in foot note 49. To this same report also may be referred the reader interested in the lithological and structural details of the various divisions of the Monroe. In the 1908 report previously cited (foot note 37), Lane refers to the Upper Monroe, or Detroit River series, as "Eo-Devonian" implying a very close relationship with the Devonian as indicated by the remarkable fauna of the Anderdon and Amherstburg strata. To account for these forms it is necessary to assume that a Devonian fauna had already developed, probably to the northward, and migrated into southeastern Michigan before Silurian conditions had been entirely effaced, an arm from the Cordilleran sea giving temporary communication with the interior basin. These forms began to arrive in the Flat Rock, reached their culmination in the Anderdon during the existence of normal marine conditions and some of them continued to exist side by side in the Lucas with typical Siluric forms from the North Atlantic.

Salina formation. Originally known in the New York series as the "Onondaga Salt Group," this formation is now very generally referred to as the *Salina*, on account of its large content of salt, either in the form of rock salt, or in solution as brine. In southeastern Michigan, it consists of alternating layers of compact, brown to drab dolomite; anhydrite, more or less converted into gypsum and pure to impure strata of rock salt. In the deep well at Royal Oak (Oakland County), there is indicated the surprising development of 932 feet of this formation, of which 609 feet are reported as salt. Along Detroit River, the thickness is considerable, although less and diminishes gradually to the southward. With the disappearance of the beds of rock salt in the Church and Company wells, just north of Trenton, there is no means of distinguishing the Salina dolomites from those of the overlying Monroe in the well records to the south. In the Ohio scale, the formation is not now recognized as was originally done by Newberry.[58]

The wells of the Solvay Process Company, near Detroit, furnish a thickness of 709 to 748 feet, and an average of 732 feet, but with no certain knowledge that the entire series was penetrated.

58. Newberry, Report of the Geological Survey of Ohio, vol. I, 1873, p. 132.
Orton, Report of the Geological Survey of Ohio, vol. VI, 1888, p. 15.
Prosser, Geological Survey of Ohio, Bulletin No. 7, 1905, p. 3.

Similarly at the Oakwood salt shaft, the preliminary test well showed 792 feet that should be referred to the Salina. The shaft itself has thus far penetrated but 150 feet of the series and with the drill cores of the preliminary test well, gives us the first definite information relative to the stratigraphy of this portion of the formation. The revelations of this difficult and expensive piece of engineering are of such geological interest and of such economic importance that a description and complete log of the shaft will be given upon a subsequent page of this report. Reference to this log shows a succession of dolomites, salt and a mixture of these two materials, in some instances the dolomitic slime simply clouding the salt, in other cases with only a few disconnected crystals of salt embedded in the dolomitic matrix. Exposed to the weather upon the dump, the salt is soon dissolved and a honey-combed mass of brown or drab dolomite remains. Thin seams of greenish shale occur at certain horizons, becoming black and carbonaceous at times. Whereas the Monroe beds are characterized by heavy flows of water highly charged with hydrogen sulphide, the Salina is absolutely free from such flows and the tunnels radiating from the shaft are almost dusty. What are believed to be marketable strata of salt give a total of 454 feet, the heaviest bed having the enormous thickness of 369 feet. When entered, it will probably be found that this bed is really divided into two, or more, by thin layers of dolomite, as seen in a number of the Solvay wells. Careful search of the rock fragments brought up from the shaft failed to reveal any trace of fossils, plant or animal.

Passing southward from the Detroit region the deep well of the River Rouge Improvement Company, shows, at least, 723 feet of Salina, of which 378 feet are rock salt. At the bottom of the series, two beds, 120 feet and 78 feet in thickness respectively, are separated by 15 feet of a salty shale. Just above lie 125 feet of what is described by the driller also as "salt shale." The well record of the Eureka Iron Company at Wyandotte is interpreted by Lane as showing some 770 feet of Salina, but with the salt strata aggregating only 160 feet. The lowest bed of the series has a thickness of 110 feet and is the correlative, presumably, of the very heavy bed to the north. Here it is underlain by 310 feet of strata also referred to the same formation before the Niagara is reached. If this reference is correct, the heavy salt bed lies near the middle of the series and the wells in the vicinity of Detroit give only partial sections of the Salina formation, although there is, as yet, no means of knowing how rapidly these lower beds may

vary in thickness to the northward. The series of six wells of the Church and Company, just north of Trenton, enable us apparently to mark the southern limit of the rock salt in southeastern Michigan. The four wells numbered 1, 3, 4 and 6 lie in an east-west line and show but a single salt stratum 26 feet, 25 feet, 30 feet and 33 feet, respectively, in thickness. Well No. 2 lies 300 feet due south of No. 1 and gives but two feet of salt, while No. 5 lying 1350 feet to the southwest of No. 1 gave no rock salt whatever. Well No. 4 gives 650 feet for the entire Salina; gypsum (probably anhydrite) very largely replacing the salt.

The frequent association of calcium and magnesium carbonate, calcium sulphate and the strong bitter brines with rock salt, as in the region just described, gave rise more than a century ago to the theory that they must all have originated from the evaporation, under arid conditions, of detached arms of the sea. To account, however, for such extensive beds of salt, gypsum and dolomite demanded depths for these inland seas which overtaxed ones belief. Furthermore, the deposits alternated in succession and were often interstratified with shale and sandstone, so that the simple evaporation of such a sea could furnish no adequate explanation. Laboratory experiments have shown that, when sea water is evaporated, there are first thrown down the calcium carbonate ($CaCO_3$) and hydrous oxide of iron ($2\ Fe_2O_3+3\ H_2O$; next about 84% of the calcium sulphate ($CaSO_4$) in solution. There is next precipitated upon further concentration about 54% of the salt (NaCl) along with the balance of the calcium sulphate, followed by 8.5% of salt free from this sulphate. The remaining salt with the more soluble compounds of magnesium, potassium, bromine and iodine, finally crystallized in various combinations, or constituted the *bittern* in case evaporation was not complete. As pointed out by Hubbard (foot note 60), when such simple concentration of an inland sea takes place, the bottom and sides would be coated with calcium carbonate, more or less stained with iron, upon which would be deposited a layer of gypsum or anhydrite. The concentrated brine would shrink to the deeper portions of the basin and there be precipitated along with more gypsum, the final salt layers being practically pure. If the evaporation were not completed the bittern, or "mother liquor," would remain as a concentrated mineral water, to be incorporated into subsequent deposits. To account for a succession of the above series, for irregularities and for shale and sandstone, it has been supposed that influxes of the sea took place, as during storm, or exceptionally high tides, bringing in

fresh supplies of sea water and incidentally mud and sand.[59] The enormous thickness of any single deposit, however can not be so explained.

In 1877 Ochsenius proposed a modification of this theory by assuming a basin of sufficient depth which continuously maintained its connection with the adjacent ocean, the water of the basin evaporating and allowing a constant inflow of sea water. The concentrated surface layers will sink, encountering layers differently charged and giving rise to the deposition of various compounds, chiefly salt and gypsum. Given sufficient time, a basin of sufficient original depth or in process of slow subsidence, the continuance of uniform conditions and an extensive bed of any of the above substances might take place. This is the theory accepted by Hubbard as explaining most satisfactorily the Salina series of Michigan.[60] Grabau has recently pointed out that according to this theory there should be found abundant remains of marine organisms in the strata enclosing the salt, and it would seem, even in the salt itself. The constant influx of sea water would sweep in countless forms whose remains would settle to the bottom, whether or not they had been able to maintain themselves alive for any considerable time in the water undergoing concentration. It has already been pointed out that the Salina strata are practically barren of fossils. Grabau further calls attention to the absence of marine strata, outside of the Salina area of Michigan, Ontario and New York, which might be regarded as contemporary with the salt and gypsum strata.[61] The complete absence of such strata, this author convincingly argues, indicates a land-locked basin, or series of such in which the Salina beds are to be laid down. Widespread desert conditions with intermittent streams; long continued erosion of pre-Salina strata containing imprisoned sea-salts; the solution, transportation and final concentration of these salts in the various basins, he believes most satisfactorily explains all the phenomena of the Salina. From computations, this author concludes that the erosion of 400 feet of Niagara limestone from Minnesota, Wisconsin, the upper Great Lake region and western Ontario would be sufficient to yield 100 feet of pure rock salt distributed over an area of 25,000 square miles.

The very general absence of fossils makes it rather difficult to account for the dolomitic strata which make up the bulk of this series and the Lower Monroe as well. Some of this may have

59. See Winchell, Geological Studies, 1886, p. 186.
60. Hubbard, Geological Survey of Michigan, vol. V, part II, 1895, p. IX.
61. Grabau, Physical and Faunal Evolution of North America during Ordovicic, Siluric and Early Devonic Time: Journal of Geology, vol. XVII, 1909, p. 245. See also The Monroe Formation: Michigan Geological and Biological Survey, 1910, p. 226.

been originally deposited as dolomitic slime resulting from the destruction of earlier dolomitic strata, but the fact that the oölitic particles and brachiopods were certainly transformed from calcium carbonate into the calcium-magnesium carbonate, known as dolomite, makes it appear that the alteration was possible in the sea itself or subsequently. In the process of dolomitization, there is a theoretical shrinkage of 13.3 per cent, but most of the Monroe and Salina dolomites of this region are exceedingly compact, indicating that the conversion took place either just before or at the time of deposition of the slime. The theory which best explains the various facts observed in this locality is that much of the dolomite resulted from the alteration of chemically precipitated calcium carbonate, this change occurring at the time of deposition. The unusual conditions which permitted this change were attained in the land-locked basins of Monroe and Salina time. During Anderdon time (Upper Monroe), normal marine conditions seem to have prevailed and the organisms furnished the great bulk of the calcium carbonate that was then deposited over the sea bottom. There occurs one very compact stratum, however, in the Sibley and Anderdon quarries, in which fossils are absent, the rock delicately laminated and which furnished an analysis of 100 per cent calcium carbonate. It seems quite probable that this stratum was chemically precipitated from the sea water directly from the breaking down of the very unstable calcium bicarbonate ($CaH_2C_2O_6$), a change now known to be taking place at the present time in connection with some of the Florida keys.

Niagara formation. This formation, named and well known because of the role which it plays in the production of the celebrated cataract, is penetrated in the deeper wells of southeastern Michigan. The log of the deep Wyandotte well shows some 360 feet of "limestone," underlain by 10 feet of "slate," which are referred by Lane to the Niagara. The so-called limestone is in reality a dolomite; compact, fine grained, light colored and hard. In color, it is thus in contrast with the drab colored dolomites of the Salina series and is not interrupted with seams of shale, salt or gypsum. There is but little content of argillaceous matter, suggesting the absence of ordinary sediment while it was forming and permitting the inference of Lane that the arid conditions of Salina time had already made their appearance.[62] This inference relative to the climate receives confirmation from the very low percentage of iron present in the rock, the occasional presence of apparently wind-

62. Annual Report for 1908, p. 57. Also vol. V, pt. II, p. 29.

blown sand grains and the fact that the strata are overlain by the salt and gypsum deposits of the Lower Monroe.

In Ohio the Niagara formation is known in outcrop, giving an opportunity for the study of its characteristic fossils and its subdivision.[63] Four groups of strata are there recognized; a sandstone, two series of dolomites and a basal shale layer. The sandstone (Hillsboro) has no representative in Michigan but the Guelph—from the typical locality in Ontario—maintains a development of some 200 feet across Ohio to the northward. Beneath the Guelph, lies the so-called "Niagara limestone," or Lockport, an even-bedded, blue to drab dolomite which is best developed in southern Ohio and thins out and is unrecognizable toward the north, even in its outcrop. For this reason, as well as from its color, it seems probable that the Michigan representative is the Guelph. The lowest member of the series is the Niagara shale, a mass of light-colored clays with numerous calcareous bands, showing a thickness of 100 feet in southern Ohio, but thinning towards the north to but a few feet, or being entirely absent. In the Wyandotte well, this division of the Niagara is represented by 10 feet of "slate." There is reason for believing that the dolomitic member, or members, of the Niagara underlie the entire Lower Peninsula and that it will be reached in all wells that penetrate its horizon. Its outcrop in Michigan is seen only along the northern border of lakes Michigan and Huron, in the southern margin of the Upper Peninsula, where at a few localities it is utilized in the manufacture of lime. Unusually fine exposures occur upon Drummonds Island, affording a choice series of fossils, especially corals. Rominger made the fullest study of the group in this northern locality and recognized three divisions, all dolomitic except a few thin layers, or irregular patches of limestone.[64] The uppermost division consists of a series of thin, uneven layers, carrying seams and nodules of chert, and containing the greatest abundance of fossils. The middle division consists of massive, highly crystalline ledges with casts or poorly preserved fossils. The lowest division shows fossils but rarely, is very regular and even-bedded, but composed of thin layers of fine, crystalline grains. This author expresses no opinion as to the approximate total thickness of the group. The logs of two deep wells at St. Ignace are now available giving two complete sections of the formation.[65] In the older of the two, there is shown 300 feet of Niagara (depth 504 to 804 feet) and in the second, which lies

63. Orton, Geological Survey of Ohio, vol. VI, 1888, p. 13.
64. Rominger, Geological Survey of Michigan, vol. I, pt. III, 1873, p. 37.
65. See vol. V, Geological Survey of Michigan, 1895, pl. LXIII. Annual Report for 1901 p. 228.

about two miles north, a thickness of 510 feet (depth 510 to 1020 feet). Rominger published the analyses of 10 specimens of the Niagara dolomite, showing a range of 52 to 62% of calcium carbonate, 32 to 43% of magnesium carbonate, 1 to 3% of alumina and iron and 1 to 9% of insoluble residue (*loc. cit.*, p. 48). In the limestone layers, the calcium carbonate ran as high as 95%, indicating a true limestone.

DEEPER BEDS REACHED BY BORINGS.

Beneath the Niagara formation and between it and the much sought for Trenton limestone, there intervene approximately 600 feet of sedimentary strata, mostly shale, with some sand. These layers are believed to represent in part the Clinton and Medina formations, often highly stained with iron and belonging to the Silurian System. In the Wyandotte well, which alone furnishes a section of these strata in Wayne County, it is difficult to draw any line of division between them. Beneath these lie the Hudson River and Utica shales, grayish to bluish, more or less dolomitic, or calcareous, and passing below into black. These two, with the underlying Trenton, represent the Ordovician System in Michigan. Along with the Clinton and Medina they are only imperfectly known in outcrop in the Upper Peninsula, skirting on the northward the belt of Niagara. Over the Lower Peninsula they are deeply buried and reached only in the deeper wells along the northern and southern portions, outcropping again in southern Ohio. Southward the carbonates become more prominent than in Michigan, indicating their formation under off-shore conditions. The entire series indicates a shallowing of the Palaeozoic sea in this region, and an increase in the erosion of neighboring land areas and consequent sedimentation, an intermediate stage between the open sea conditions of Trenton and Niagara time. For a fuller discussion of these strata in Michigan, the reader is referred to recent papers in the Report of the State Board of Geological Survey of Michigan for the year 1908, pp. 23 to 105.

Notes on the Geological Section of Michigan for geologists, teachers and drillers.

Part I. The Preordovician, by A. C. Lane and A. E. Seaman, p. 23.

Part II. From the St. Peters up, by A. C. Lane, p. 43.

CHAPTER VII.

WATER RESOURCES.

Rapid increase in the density of population of any section makes the problem of a wholesome and sufficient water supply more and more difficult of solution. This difficulty arises not only from the relatively greater consumption but from complicated factors connected with its distribution, disposal of sewage, protection from fire, etc. To supply with water the army of people making up the population of Wayne County, nearly one-fifth of that of the entire state, there are four chief sources available:

1. Surface waters: streams, lakes, ponds, reservoirs and cisterns.
2. Waters from former lake and river deposits.
3. Waters from deposits of the ancient ice sheets.
4. Waters from the bedrock.

As generally understood, the source of all these waters is the atmosphere, from which the moisture is condensed and precipitated as rain, snow, hail, etc. However, when subjected to various conditions after precipitation, the waters become essentially different and typical samples from each source may generally be readily distinguished.

SURFACE WATERS.

Reservoirs and cisterns. From data obtained from Prof. M. E. Cooley, of the University of Michigan, Lane calculated that 38% of the total precipitation of a region may be collected from roofs and secured in cisterns and that with a rainfall of 32 inches, practically the same as that of Detroit, every 100 square feet of horizontal surface may yield 100 cubic feet of water annually, or about 25 barrels.[1] This is but a little over one-third of what actually falls upon the area, the remainder being lost in wetting the roof, evaporation, overflow during heavy rains, blowing or sliding of snow, etc. Where limited quantities of practically pure water are desired, simple precautions would enable one to secure a greater

1. Water-Supply and Irrigation Paper No. 30, 1899, p. 45.

yield. In addition to the dust, coal dirt and organic matter derived from the collecting surface and also from the atmosphere as well, this water contains appreciable quantities of ammonia, nitric and nitrous acid, sulphuric and sulphurous acid, nitrites, nitrates and sulphates, along with carbon dioxide and other gases of the atmosphere. For the laundry, and in some cases for full domestic use, this type of water is collected in cisterns or tanks and utilized. Where wells are especially difficult to obtain, these artificial reservoirs are connected with the barn and used in watering stock. Excavations in the old lake clays for the manufacture of brick serve as collecting basins for surface water and supply the necessary water for the softening of the stiff clays. These and other excavations made directly for the purpose often serve as ponds for ducks and geese.

Ponds and lakes. In striking contrast with Oakland to the north and Washtenaw to the west, the county of Wayne is surprisingly deficient in ponds and lakes. Aside from the small bayous found upon the river flats, the only natural lakelet in the county lies one mile east of Northville (Sec. 2, Northville township) and is known locally as Yerkes Lake (Pl. XXVI). It has a maximum diameter of about 1100 feet and is drained at higher stages than at present by a small stream into the Middle Rouge. Occupying a depression between the morainic knolls of the region, it receives considerable surface drainage and is said also to be fed with springs and to be well stocked with fish. Owing to its slight elevation (below 800 feet), it had to be rejected as the source of supply for the village of Northville.

A small artificial lakelet for ornamental purposes is maintained at Eloise, an excavation having been made into the glacial clay and supplied with water which is piped from the Rouge flats to the north. Although so poorly supplied with inland lakes, Wayne County reaches Lake St. Clair upon the north and extends to Lake Erie upon the south. The water of Lake St. Clair is utilized to a greater or less extent by the residents of Grosse Point township. Many of those who adjoin the lake, pump the water direct by means of windmills and distribute it over their grounds from elevated storage tanks. Drinking water is ordinarily derived from wells into the drift, or exceptionally from the bedrock. The village of Grosse Point Farms is supplied with water from the lake drawn at a point about 1¾ miles from the shore, this distance being necessitated by the shallow condition of the lake. The water

flows by gravity into a settling basin from which it is pumped direct.[2]

Surface streams. Aside from Detroit River, the surface streams of the county are utilized to but a slight extent as a source of water, except for the watering of stock and sprinkling of small truck farms. The very irregular flow of the Rouge and its usual turbid condition have prevented its utilization as a water resource. At Dearborn, the Arno Mills use the water of the Lower Branch in their dyeing business and the main branch for a time furnished water for the boilers in the power plant of the Detroit, Ypsilanti, Ann Arbor and Jackson Railway. At Eloise, the Rouge water is used for the boilers of the Wayne County House, for sprinkling, in flushing the sewers, etc. It was originally pumped direct from the Lower Rouge but is now obtained from the flats of the Middle Rouge near Perrinsville, 3¾ miles distant. A well 35 feet in diameter and 18 feet deep has been constructed (1902), which receives the flow from the river along with surface drainage and the latter necessitates a filtering plant at Eloise. The composition of the water of the Middle Rouge is shown in the following table, the analysis having been made by L. M. Gelston, then Assistant Director of the University of Michigan Laboratory of Hygiene, Ann Arbor.

TABLE XLV. ANALYSIS OF WATER FROM MIDDLE RIVER ROUGE.

(*Parts per million*).

Inorganic matter	732	Free ammonia	0.133
Organic matter	96	Albuminoid ammonia	.124
Chlorine	37	Total residue by evaporation	828.
Potassium	1.5		

Reaction neutral. Algae, protozoa, and bacteria present.

In a suit brought against the infirmary in 1898 for the pollution of the Lower Rouge, the following analyses were made by Prof. J. E. Clark, M. D., of the Detroit College of Medicine. It was then legally decided that the Rouge was being seriously contaminated, and the institution was required to put in settling basins for its sewage. A series of such basins is now in use, the sewage being treated with alum and lime and then filtered through gravel.

2. Statistics relative to the various village and city water supplies of Wayne County, as well as the water powers, were collected by the writer and published in Water-Supply and Irrigation Paper No. 182, 1906, which the reader may obtain by application to the United States Geological Survey, Washington, D. C.

TABLE XLVI. ANALYSES OF WATER FROM LOWER BRANCH RIVER ROUGE SHOWING CONTAMINATION.

(*Parts per million*).

	Above sewer.	From sewer.	250 to 300 ft. below sewer.
Inorganic	280	740	720
Organic matter	150	380	370
Chlorine	5	105	95
Free ammonia	.302	48.8	1.512
Albuminoid ammonia	.366	32.58	1.44
Total solids	430	1,120	1,090
Bacteria	10,900	325,000	12,500

The table is of especial interest, since it shows the normal condition of the stream water as well as those substances indicating serious sewage contamination. The amount of chlorine, combined to form common salt, has been increased 19 fold, while the ammonia has not risen in proportion to the amount actually present in the sewage itself. A complete analysis of the water would have shown that much of this had been oxidized into nitrites and nitrates, which, along with the chlorine, furnish an index to the probable amount of sewage contamination. A comparison of the amount of inorganic matter in the waters of the Middle and Lower branches shows that the former is considerably harder, due undoubtedly to the fact that it is more abundantly fed by springs along its course.

Aside from the incidental use by the farmers along its course, the water of the Huron is utilized only at one place—French Landing, for the disposition of the garbage collected from the city of Detroit. Before entering the county, it has already received the sewage from Ann Arbor and Ypsilanti, with a combined population of 21,047. Owing to the rapid and tortuous course of the river, it is likely that this contamination is rendered harmless before entering the county, although none of the villages have thus far cared to utilize this supply. The following analysis of the Huron water has been very kindly supplied by Mr. Roy W. Pryer, of the Hygienic Laboratory of the University of Michigan.

TABLE XLVII. ANALYSIS OF HURON RIVER WATER.

Sample taken at Ann Arbor, Mich., June 22, 1911.

Analyst Roy W. Pryer, Ann Arbor, July, 1911.

(*Parts per million*).

Color	slight yellow.
Odor	fishy.
Reaction	alkaline.
Hardness	162.8
Total solids	390
Loss on Ignition	192
Inorganic residue	198
Of this	
Sodium chloride ($NaCl$)	15
Calcium sulphate ($CaSO_4$)	72.3
Calcium carbonate ($CaCO_3$)	41.3
Magnesium carbonate ($MgCO_3$)	69.4
Parts potassium permanganate reduced by organic matter	16.95
Free ammonia (as NH_3)	.25
Albuminoid ammonia (as NH_3)	.38
Nitrates as N_2O_5	.2
Nitrites as N_2O_3	.01

Water powers have been developed for grinding purposes at certain favorable points along the Middle and North branches of the Rouge and along the Huron. Owing to the irregular flow and great reduction during the summer months, the water power must be supplemented with steam, or the turbines operated but a portion of the time. The heavy floods in the spring, often with the help of the ice, occasionally lead to the destruction of the dams. Both of these difficulties will be obviated by establishing great storage reservoirs by which the surplus water may be held back and dealt out as needed.

At the Yerkes Flouring Mill, upon the Middle Rouge, at Northville, there is a head of 16 feet and an available horse power of 40. The Argo Mills at the same place have 12 feet head and 20 horse power available. Upon the same stream at Plymouth, there are also two mills in operation, the Phoenix and Plymouth mills, each with a head of about 16 feet and developing 80 and 45 horse power respectively. Between Northville and Plymouth, at Waterford, there is an abandoned mill and power. At Pikes Peak, the Nan-

The city of Detroit, with its population of 465,766 souls (1910) and area of approximately 42 square miles, is supplied with this water from a single pumping station, believed to be the largest in the world. This station is located in the extreme eastern part of the city, opposite Belle Isle, and the water is taken from the head of the island through a tunnel of recent construction.[5] In addition to the city itself, this station also supplies water to the suburban villages of Hamtramck (population 3,559), Highland Park (4,120), River Rouge (4,163) and Oakwood (781); with a combined population of 12,623. This water is all metered and double the city rates are charged. With the system of direct pressure, it has been found impracticable to force the water to all parts of the city, portions of which are 60 to 70 feet above the river, and to the upper floors of the taller buildings. Accordingly, in 1898, a double system was installed each with its own set of pumps and mains, one operated under low and the other under high pressure. However, buildings over five stories high are provided with their own private pumps.

Although naturally of most excellent quality, this abundant water supply is subject to more or less contamination from surface drainage. Not far from 400,000 people reside in the St. Clair drainage basin between Detroit and Port Huron. There are many truck farms, rich in compost, the drainage from which in the early spring and after heavy rains is a menace to the city's health. Prof. Gardner S. Williams, lately of the University of Michigan, has demonstrated that the dredging of the delta of Black River, Port Huron, by the United States Government in 1892 was responsible for the outbreak of typhoid in Detroit during June of that year.[6] Compared with many other cities, the city of Detroit has a very low death rate from this disease, averaging during the past five years 87 deaths or from 4 to 5 deaths for each thousand inhabitants. In view of this low rate, there is little reason to suspect that the germs are ordinarily derived from the river, although there is the possibility that they may be at any time. A number of local outbreaks during the past two years have been traced to the milk supply, the contamination occurring in the dairies and, undoubtedly, numerous cases each summer are contracted outside,

5. Detailed data relative to the Detroit Water Works will be found in the annual reports of the Detroit Water Board. An interesting article appeared in the Engineering Record, vol. 47, No. 25, 1903, p. 650, by Clarence W. Hubbell. See also Water-Supply and Irrigation Paper, No. 182, 1906, p. 53.

6. Williams, Typhoid Fever and the Water Supply of Detroit: Proceedings of the Sanitary Convention, Detroit, 1897, p. 90.

maximum velocity is 2½ miles an hour, and the average somewhat less than 2 miles. During July and August, 1897, detailed measurements of the flow were made by Clarence W. Hubbell, engineer of the Detroit waterworks. Float methods gave an average flow of 65,000 cubic feet a second and current meters one of 53,000 cubic feet for this channel. When the channel is covered with ice and the Canadian channel is open, the flow is reduced to 36,000 cubic feet a second. The temperature of the water ranges from 32° to 70° F., and the greatest vertical range between the top and bottom has never been observed to exceed one-half degree. Between shore and midstream, the temperature of the water may vary as much as 8° or 9°, and this fact may be used to detect possible contamination from tributary streams. Lake St. Clair, which extends practically to the city, has served for many centuries as a great settling basin, as is evidenced by its shallow condition and the delta at its head. The turbidity of the water is low, except immediately following storms, when the bottom of Lake St. Clair becomes more or less disturbed and the tributaries bring in sediment. The following analyses, made some eight years apart, are of interest in showing the nature and amount of mineral matter contained in this water. The total solids is thus seen to be small, well adapting the water to use in various manufacturing plants, a matter of great importance to such a rapidily growing city.

TABLE XLVIII. MINERAL ANALYSES OF DETROIT RIVER WATER.

(Parts per million).

Calcium (Ca)	[3]24.610	[4]23.800
Magnesium (Mg)	7.440	5.400
Aluminum (Al)	1.800	......
Iron (Fe)	Trace	......
Alumina (Al_2O_3) and Ferric oxide (Fe_2O_3)		11.100
Sodium (Na)	2.760	2.910
Potassium (K)	Trace	0.0576
Chlorine (Cl)	2.990	4.550
Silica (SiO_2)	1.590	7.500
Carbonate radical (CO_3)	50.850	CO_2 30.120
Sulphate radical (SO_4)	7.620	8.630
Organic and volatile matter	36.390	38.540
Total mineral matter	101.240	Total solids....109.640

3. Twenty-first Annual Report of the Michigan Board of Health, 1902, p. 63. (Recomputed to ionic form by the United States Geological Survey.)
4. Twenty-eighth Annual Report of the Board of Health of the City of Detroit, 1909, p. 97. For other analyses see Lane, Lower Michigan Mineral Waters: Water-Supply and Irrigation Paper No. 31, 1899, pp. 18 and 19.

The city of Detroit, with its population of 465,766 souls (1910) and area of approximately 42 square miles, is supplied with this water from a single pumping station, believed to be the largest in the world. This station is located in the extreme eastern part of the city, opposite Belle Isle, and the water is taken from the head of the island through a tunnel of recent construction.[5] In addition to the city itself, this station also supplies water to the suburban villages of Hamtramck (population 3,559), Highland Park (4,120), River Rouge (4,163) and Oakwood (781); with a combined population of 12,623. This water is all metered and double the city rates are charged. With the system of direct pressure, it has been found impracticable to force the water to all parts of the city, portions of which are 60 to 70 feet above the river, and to the upper floors of the taller buildings. Accordingly, in 1898, a double system was installed each with its own set of pumps and mains, one operated under low and the other under high pressure. However, buildings over five stories high are provided with their own private pumps.

Although naturally of most excellent quality, this abundant water supply is subject to more or less contamination from surface drainage. Not far from 400,000 people reside in the St. Clair drainage basin between Detroit and Port Huron. There are many truck farms, rich in compost, the drainage from which in the early spring and after heavy rains is a menace to the city's health. Prof. Gardner S. Williams, lately of the University of Michigan, has demonstrated that the dredging of the delta of Black River, Port Huron, by the United States Government in 1892 was responsible for the outbreak of typhoid in Detroit during June of that year.[6] Compared with many other cities, the city of Detroit has a very low death rate from this disease, averaging during the past five years 87 deaths or from 4 to 5 deaths for each thousand inhabitants. In view of this low rate, there is little reason to suspect that the germs are ordinarily derived from the river, although there is the possibility that they may be at any time. A number of local outbreaks during the past two years have been traced to the milk supply, the contamination occurring in the dairies and, undoubtedly, numerous cases each summer are contracted outside,

5. Detailed data relative to the Detroit Water Works will be found in the annual reports of the Detroit Water Board. An interesting article appeared in the Engineering Record, vol. 47, No. 25, 1903, p. 650, by Clarence W. Hubbell. See also Water-Supply and Irrigation Paper, No. 182, 1906, p. 53.

6. Williams, Typhoid Fever and the Water Supply of Detroit: Proceedings of the Sanitary Convention, Detroit, 1897, p. 90.

TABLE XLIX.—SANITARY ANALYSES OF DETROIT RIVER WATER.

(Parts per million.)

	July, 1901.	August, 1901.	Sept., 1901.	Oct., 1901.	Nov., 1901.	Dec., 1901.	Jan., 1902.	Feb., 1902.	March, 1902.	April, 1902.	May, 1902.	June, 1902.
Appearance	C.	C.	C.	C.	C.	C.	C.	N. C.	N. C.	S. T.	S. T.	N. C.
Total Solids	108.4	104.2	103.0	111.0	104.0	111.0	106.2	115.0	116.4	116.0	118.2	112.0
Volatile matter	41.4	36.4	44.4	41.8	34.8	41.6	39.6	39.0	36.8	39.0	40.0	40.0
Non-volatile matter	67.0	67.8	58.6	69.2	69.2	69.4	66.6	76.0	79.6	77.0	78.2	72.0
Free ammonia	.008	.006	.020	.016	.024	.012	.026	.028	.024	.016	.022	.020
Albuminoid ammonia	.074	.080	.126	.116	.092	.102	.082	.086	.092	.086	.082	.118
Nitrogen as nitrates	.115	.082	.164	.210	.099	.198	.230	.148	.115	.164	.198	.165
Nitrogen as nitrites	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Chlorine	2.80	2.90	2.60	2.80	2.70	3.15	2.70	3.15	2.50	2.75	3.10	2.70
Oxygen absorbed in 15 minutes	.40	.32	.44	.48	.44	.48	.40	.36	.44	.40	.32	.28
Oxygen absorbed in 4 hours	.76	.72	.88	.96	.84	.72	.76	.84	.88	.80	.84	.88
Bacteria per cubic centimeter	98	106	37	37	103	104	87	124	170	105	31	398
Bacteria per cubic centimeter	43	84	98	104	170	199	132	353	105	190	48	34
Bacteria per cubic centimeter	116	192	160	82	89	265	26	197	266	235	66	140
Bacteria per cubic centimeter	62	47	52	206	204	99	204	402	333	302	115	69
Growth in .2 per ct. carbolic-acid gelatin	None.	None.	None.	None.	None.	None.	None.	None.	None.	None.	None.	None.

C.—Clear. N. C.—Nearly Clear. S. T.—Slightly Turbid.

and imported into the city. The officials of the city Board of Health are fully awake to the danger and are doing all in their power to guard the public health, making frequent sanitary analyses of the river water and each year recommending strongly the establishment of a municipal filtering plant. The preceding analyses, taken from their Twenty-first Annual Report, 1902, are of interest as showing the monthly variations in the character of the water.

Below Detroit, the city of Wyandotte and the villages of Ford and Trenton also draw their water supply from the river by separate pumping plants. Upon Grosse Isle, this water is also pumped by means of wind mills into storage tanks, from which it is distributed by gravity. Since practically all the water pumped by the Detroit plant finds its way sooner or later into the river again as sewage, or surface drainage, this means that some 85,000,000 gallons of polluted water are returned daily. If we assume that 50% of the rainfall, after collecting the filth from the roofs, streets, walks and gutters, also reaches the river, we have some 22,000,000 of gallons as a daily average from this source. The Canadian towns opposite Detroit—Walkerville, Windsor and Sandwich, with a combined population of some 20,000, contribute to the river some 6,000,000 additional gallons of sewage. The grand total of this unsavory beverage gives about 17.5 cubic feet a second, or about one gallon for every 12,000, on the supposition that it is evenly distributed. However, the Detroit drainage hugs the western bank from the mouth of the sewers to the intake pipes and in five to six hours the contents of Detroit sewers may be delivered to unsuspecting victims farther down the river. This gives insufficient time for the process of oxidation to complete its work of purification of organic refuse and bring about the death of the disease germs. Then, too, it must be remembered that it is not a matter of the *quantity* of contaminating material, but rather of its *quality* and that Detroit has upon an average some 1000 to 1500 cases of typhoid annually. Below Wyandotte the conditions are still more serious as further pollution has occurred from its sewers and the water is confined in the relatively narrow western channel. One resident of the region informed the writer that he was cured of wanting to drink this water by observing the nature of the spray tossed upon the deck of a motor boat in which he was riding. Another had noted the appearance of the water when seen through thin, clear ice in the winter.

The question of water supply for the lower Detroit River section is one for the trained engineers to settle. To the geologist, several

solutions are in sight—a municipal filtering plant for each, or a single one for all; the extension of the Detroit mains to Trenton; the use of deep wells such as that upon Grosse Isle for household use, the river water still being used for manufacturing, laundry, fire and lawn purposes. In the Free Press of June 11, 1911, the suggestion of Richard P. Joy is worth consideration by those interested. This involves the construction of a canal, or aqueduct, from Port Huron to Lake Erie which would furnish the entire series of cities and villages with a wholesome and adequate water supply, well adapted to the various uses. Until some feasible plan can be devised, it is the height of wisdom for all people using the river water to either boil, or thoroughly filter, all water used for drinking, or that in any way comes in contact with food or utensils used in its preparation or serving.

That the people of this region are being aroused to the seriousness of the matter is indicated by the demand for bottled spring waters, two varieties of which are now available. One is shipped in from Rochester, Michigan, and is delivered for 10 cents a gallon; the other is known as "Maple Spring Water," from a bored well upon the place of J. H. Vreeland, NW. 1/4 NE. 1/4, sec. 12, Monguagon township. The well is 65 feet deep, entering rock some 5 feet, and flowed up to about one year ago; ceasing, the owner thinks, owing to the great amount of drainage at the Livingstone cut or Sibley quarry. The water contains some gas when first pumped, either carbon or sulphur dioxide, which is allowed to escape when it is bottled and delivered to customers for 5 cents a gallon.

WATERS FROM LACUSTRINE AND RIVER DEPOSITS.

In Chapter III of this report, there has been described a series of beaches, terraces and river deltas formed during the closing stages of the Glacial Epoch as the result of wind, wave and stream action. These consist of hillocks of sand, or gravel and sand, attaining a thickness of 25 to 30 feet, resting upon the underlying clay. At times, the deposit is of the nature of a thin sheet which serves as a veneering over the glacial clay and often covering many square miles of territory. These loose, unconsolidated deposits are very porous, 30% of their volume sometimes being pore space, and readily absorb a large percentage of the rainfall unless the ground is frozen or covered with snow or ice. With a precipitation of 32 inches and a run-off of 25% there would be an average daily absorption of 132,210 cubic feet over every square mile, or nearly 1,000,000 gallons. This sinks until stopped by the

impervious clay beneath where it is either held in depressions, or slowly works its way along the slope of the clay surface.

Shallow wells. The absorption of this vast amount of water often takes place faster than it can escape and the level of the groundwater rises and often lies quite near the surface, easily reached by shallow wells, ranging from 5 or 6 feet to 20 or 25 feet, a very common depth being 10 to 15 feet. From the way in which this water is held, it is obvious that it would possess no "head." As a rule, these wells are dug, although sometimes driven, and cased with barrels, planks, brick, stone or crocks. The water is obtained usually either by suction or chain pumps, the wind mill being occasionally used. In some cases the bucket, with chain, rope or pole, is used for dipping up the water; even the old-fashioned sweep being occasionally seen. It is not ordinarily necessary to strike clay in sinking the well, unless the supply is scant, when an excavation into the clay becomes desirable. Generally the supply is reported to be sufficient for domestic purposes, and is often abundant. It, however, fluctuates with the season and after prolonged drought may entirely fail. In sinking wells it is desirable to reach the level of ground water at the time of a prolonged dry season in order to secure a permanent yield. The principle involved is shown in the accompanying figure.

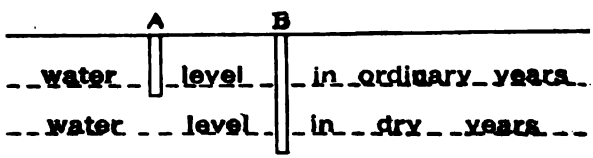


Fig. 17. Diagram showing relation between depth and permanence of wells. A. Well sunk to ordinary water level, but failing in times of drought. B. Well sunk to level of water in dry years and never failing (From U. S. Geological Survey Water-Supply Paper No. 255).

In one-third of the wells from which data were procured, the owners report the water as "soft" and suitable for laundry use, no cisterns being required. This indicates that but little calcium or magnesium carbonate has been dissolved from the sand or gravel because of the absence of these materials originally, because they have been leached out or more probably, because the water has not had time to get these substances into solution. In the remaining two-thirds of the wells, the water was pronounced "hard," particularly those which approach or reach the clay. In a few instances, the water was reported to have changed from soft to hard, or *vice versa.* Other mineral ingredients, so commonly pres-

ent in other types of well water, are either absent or only very sparingly present. The temperature of the water in these wells fluctuates more than in the deeper wells, as would be expected, being affected more by the surface temperatures of the air and soil.

This type of well is obtained with the least difficulty and expense, the work being usually done by the owner himself with what little assistance he can command. Water so obtained, however, is especially liable to contamination, unless carefully guarded, since gravel and coarse sand do not make an effective filter and because of the ease with which foreign matter may enter from above. Dupuits' experiments in France have shown that the area drained by a well is in the form of an inverted cone, the radius of the base of which may range from 15 to 160 times the depth of the surface of the water in the well. This means that, if it is 10 feet from the surface of the ground to the level of the water in the well, that this well *may* receive drainage from barns and outhouses 150 to 1600 feet distant from the mouth of the well. It has also been found that a shallow well heavily pumped will drain a larger area than a deeper well subjected to moderate pumping. It thus becomes a matter of great importance to the users of the well water that it be located in the safest possible place, even if somewhat inconvenient, and it would be wise to first ascertain the probable direction of underground flow by discovering the slope of the clay surface and of the ground water. The danger of pollution is shown

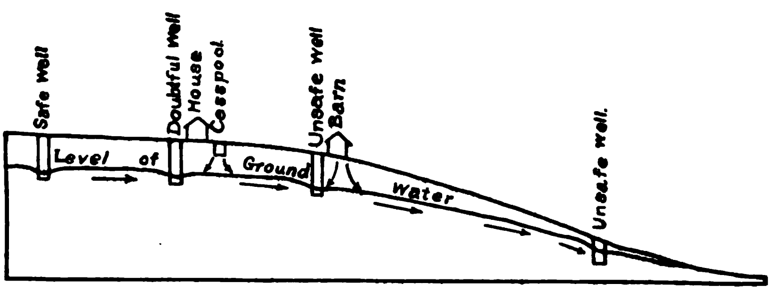


Fig. 18. Diagram showing ordinary location of farm well (From U. S. Geological Survey Water-Supply Paper No. 255).

in the accompanying diagram. It is a mistake to suppose that the surface slope of the ground controls the direction of underground drainage, the reader being able to easily construct a diagram in which the surface slopes in one direction and the surface of the impervious clay in the other. Heaping a mound of earth about the mouth of a well to keep out surface drainage from a barnyard is a very ineffective safeguard. In comparison with the dug well, the driven well is much the safer but gives a smaller

yield. The relative advantages and disadvantages of these two types of shallow wells are set forth in the following table, along with "bored" and "punched" wells. The former are made by the use of augers of various types; the latter by dropping a steel cylinder, carrying a slit upon its side for holding and lifting the material to be excavated.

TABLE L. SUMMARY OF ADVANTAGES AND DISADVANTAGES OF DIFFERENT TYPES OF WELL.[7]

Dug wells.

Advantages.	Disadvantages.
Ease of construction; can be located, sunk, and cased by owner.	Limitation to soft materials; liability to caving while being dug.
Only hand power required.	
No outfit required.	
No expensive materials required for curbing.	
Cheapness in soft material.	Costliness in hard rock.
	Wood curbing often used affords favorable conditions for the development of bacteria.
	Slight depth to which it can be sunk.
Ease of entrance of water.	Ease of entrance of polluting matter through and over top of curb.
Utilization of all water strata.	Water, not being replenished, is often stagnant.
Utilization of small seeps.	Fails frequently in time of drought.
Quick response to rainfall.	
	Must usually be at distance from house and from barns, privies, and cesspools to insure safety.
Large storage capacity.	Necessity for frequent cleaning; danger from gas while cleaning.
Accessibility for cleaning.	Short life when curbed with wood.
	Ease of entrance of animals and refuse through open top.

7. Fuller, Underground Waters for Farm Use: Water-Supply Paper No. 255, United States Geological Survey, 1910, p. 36.

Driven wells.

Advantages.	Disadvantages.
Ease of construction; often sunk in a few hours; only hand or horse power usually required.	Limitation to soft materials. Utilization of a single water stratum.
Outfit is inexpensive, can be quickly put up, and does not require skilled labor.	Usual limitation to moderate depths.
Tubing is readily obtainable and inexpensive.	Restriction to open porous water beds due to absence of storage facilities.
Cheapness.	
Safety; can be located near sources of pollution if sunk through impervious bed preventing access of contaminating matter to water bed; nothing can enter at top.	Slow response to rainfall as compared to many dug wells. Corrosion of pipes or well points. Incrustation of pipes and well points.
Permanency of supply as compared with dug wells.	Entrance of quicksand through well points. Taste of water due to solution of the iron under certain conditions.
Cleaning seldom necessary as compared to open wells.	Difficulty of cleaning in case of clogging. Short life as compared to some dug wells. Absence of information as to minor water beds or materials penetrated.

Bored wells (Arkansas type, 2 to 12 inches in diameter, tight casings).

Advantages.	Disadvantages.
Ease of construction; only hand or horse power usually required; skilled labor not essential in shallower holes.	Limitation to soft materials. Not adapted to very deep wells. Utilizes only one stratum in most places.
Cheapness for moderate depth.	Other disadvantages similar to those of drilled wells.
Deeper wells little affected by drought.	
Pollution shut out if properly cased.	
Gives good records of materials penetrated and water beds encountered.	

Punched wells.

Advantages.	Disadvantages.
When provided with pervious curbings the advantages are similar to those of open and Iowa type bored wells; when provided with tight casings, the advantages are similar to those of the Arkansas type bored wells.	Similar to those of open wells and the larger type of bored wells. Difficulty of operation; liability of crooked holes. Usual limitation to depths under 50 feet. Limitation to soft yet stiff materials, which are generally of local distribution.

In addition to safe guarding the well in every known way, great precautions should be taken in the disposition of garbage, kitchen and chamber-slops, manures, etc.; these being disposed of only at safe distances from the well that supplies the water for domestic use. The United States Department of Agriculture issues gratuitously a Farmer's Bulletin (No. 43) bearing upon the subject of Sewage Disposal on the Farm, and the Protection of Drinking Water. During outbreaks of typhoid, it is wise to apply to the Michigan State Board of Health, at Lansing, for their pamphlets dealing with the subject of the control of this expensive disease. The importance of sanitation is not generally appreciated in the rural home and should be clearly and forcibly presented in all rural schools.

Seepage springs. Around the margins of the sand dunes; wherever superficial beds of sand and gravel thin out, exposing the clay; or where these deposits are cut by surface streams to or near the clay, the water "seeps" out and gives rise to one type of springs. The flow may be slight and simply moisten the surface, or it may be concentrated into a single flow of some volume. Most of the springs of this type are seen along the banks of the Rouge and Huron rivers where they have cut into the old beaches and deltas. The conditions under which they exist are shown in the accompanying diagram.

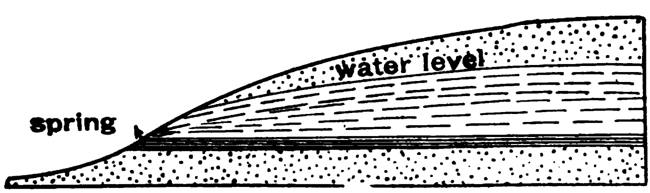


Fig. 19. Spring fed from unconfined waters in porous sands (From U. S. Geological Survey Water-Supply Paper No. 255).

In Van Buren township, some of the strongest flows are being utilized by the farmers, the water being pumped into tanks by means of hydraulic rams. These waters show only small quantities of salt, gypsum and calcium carbonate, with a little iron. The largest spring noted from this class of deposits is located upon the place G. E. Barlow, sec. 29, Livonia township. It has yielded a strong flow for many years and at the time last visited was still discharging through a 2½-inch pipe with considerable force (see Pl. XXVIII, A). Field tests showed that the water is hard, containing both calcium carbonate and sulphate but gives no reaction for salt. If this spring were fully developed, along with others upon the neighboring Rouge bank, there might be found sufficient water for such a village as Wayne, from which it is 7 miles distant. The amount of fall to this village, some 14 to 15 feet, would carry the water but could not furnish sufficient pressure. This village has been unsuccessful in securing a municipal supply from deep wells and even, at one time, seriously considered extending the Detroit mains, but the expense proved prohibitive. Recently test wells have been located to the west of the village, have been found to yield a sufficient quantity and the village was permitted to reject by ballot the question of bonding for such a water supply. At the Wayne County House, Eloise, the inmates are supplied with drinking water from a large sand dune one-half mile distant, the water being collected in small reservoirs and flowing by gravity through 3-inch tiling. The water is abundant for this purpose, pure and soft, although not making a free lather with soap.

Flowing steadily from loose deposits, spring water is more liable to be free from injurious impurities than that derived from wells. Furthermore, springs are generally more favorably situated at distances from sources of pollution than are the wells. Where build-

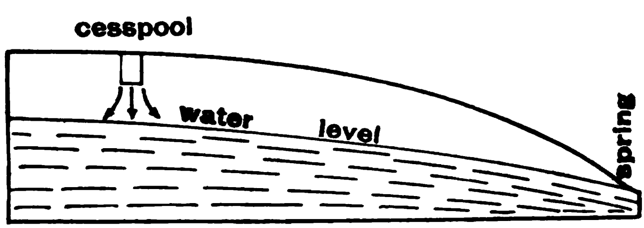


Fig. 20. Diagram showing manner in which springs may be polluted by sub-surface drainage (From U. S. Geological Survey Water-Supply Paper No. 255).

ings occupy the higher ground in their vicinity pollution may occur, however, as indicated in the accompanying diagram. If the

spring water is allowed to collect in a basin this should be carefully protected from stock, surface drainage and wind blown refuse.

WATERS FROM GLACIAL DEPOSITS.

Origin of deposits. The great Canadian ice sheets made at least three advances across this section of the state, as noted in Chapter II, from northeast to southwest, reduced much hard rock to flour and spread it over the bedrock in a sheet varying in thickness from a few feet to over 200. This deposit consists of tough, unstratified clay, generally of a blue color, with sub-angular to rounded rock fragments, and is technically known as till. Stony portions of it have become much compacted and are popularly known as "hard pan," owing to the difficulty of penetrating it in sinking wells. While this great ice mill was at work reducing the rock to powder, streams of water beneath the ice, resulting from surface melting and rains, were assorting the deposits into gravel, sand and clay. The pebbles, rounded somewhat by mutual grinding, and the sand were arranged in layers in places favorable for deposition, and these were often subsequently covered by later till deposits. The finest sediment held in suspension by the glacial torrents was carried forward to the quiet bodies of water into which these streams drained forming the fringes of deltas, or being spread as a fine layer of clay over the lake bed. As has been described, beds of a similar nature resulted from the action of waves upon the till, the sand and pebbles during times of storm being tossed upon the beach, while the clay was carried lakeward into deeper and more quiet water. Although nearly the entire county was covered by these waters, the only extensive deposits of these glacial lake clays are found to the west and north of Detroit.

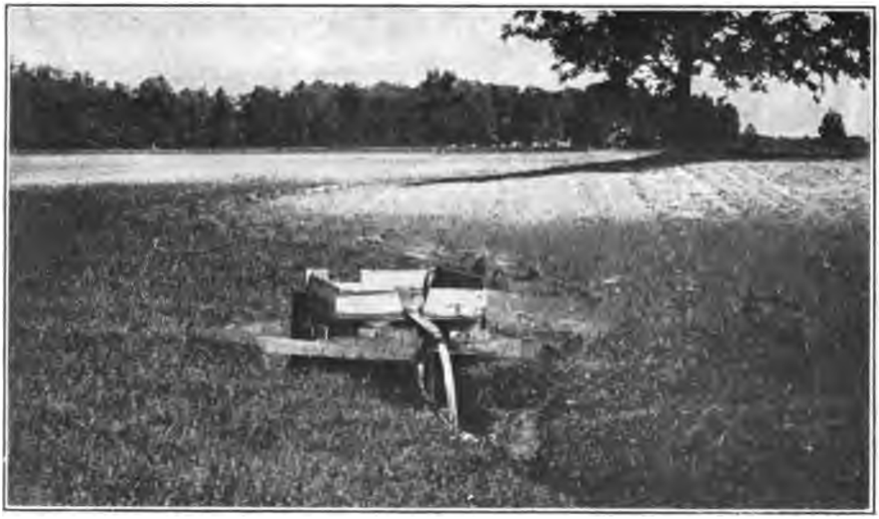
Water supply. Owing to the fineness of its pore space, lake clay and till usually contain much water but are so retentive that they act as impervious strata, yielding up little or none, but are still most valuable for confining the water bearing gravel and sand layers described. Owing to the distribution of these latter strata, the securing of a sufficient water supply is often difficult, uncertain and expensive, especially seen in the northeastern part of Van Buren, the northwestern part of Romulus and certain parts of Dearborn townships. The following expressions of the farmers indicate their varying success in obtaining water from these deposits; "dry as a powder-house," "regular lake," "oceans of water," etc. The rain water finds its way into these permeable beds of sand and gravel, often quite remote from the place at which they

are tapped by the well and often at considerably higher levels. The result is that the water confined between two impervious beds of clay enters the well under head, which may bring the level to near the surface, or may even cause it to overflow. All such wells are now spoken of as "artesian" in which the water rises by hydraulic pressure, whether they flow or not. As the water generally comes from a greater distance and from a greater depth than that of wells previously discussed, its temperature is more uniform and the supply is more abundant and more constant. In general, also, the water is more highly mineralized, owing to its better opportunities for taking the minerals it encounters in solution. Of all those wells from which data were secured, 22 per cent were reported by the owners as soft and 78 per cent as hard. Where the water is drawn from just above the bedrock, it is sometimes highly charged with minerals, such as salt, sulphur, iron, etc., which characterize the waters from the rock itself, and the inference is that the rock water has mingled with that from the glacial deposits.

Non-flowing wells. The non-flowing wells generally vary in depth from 18 or 20 feet to 100 feet or more, 60 to 75 feet being a common depth. The shallower ones are dug and lined with stone or brick; the deeper ones are driven, bored, or drilled. In some instances no casing at all is used, the clay being firm enough to maintain the necessary opening to the water-bearing stratum. Owing to the considerable depth, heavy suction pumps are generally required and windmills are in common use. The deepest wells of this type are located in the northeastern part of Van Buren, northern Canton, northern Hamtramck, and southwestern Grosse Point townships, the maximum found having a depth of 182 feet. Owing to the nearness of bedrock to the surface in Monguagon and Brownstown townships, the wells of this class are necessarily shallow, many of them stopping just short of the rock in a bed of gravel. The height to which water will rise, with reference to the surface of the ground, depends on the head and the elevation of the ground at the mouth of the well, and each of these factors grows less toward the southeast. In the belts immediately surrounding the areas of flowing wells, to be next described, the water comes very near or quite to the surface and drops back from it as we pass to the east or the west. In the wells of this class from which data were secured, 80 per cent were reported hard and 20 per cent soft. When tightly cased to a level above ground, the wells are safe from contamination. If the casing is too short at the top, or if no casing at all is used, they may receive surface drainage and become a source of danger. The collecting areas of this water

A. FLOWING WELL FROM DRIFT CLAY, CANTON TOWNSHIP.

B. PRIMITIVE TYPE OF FLOWING WELL, CANTON TOWNSHIP. FLOW GREATLY REDUCED BY CLOGGING OR LEAKAGE.



A. NATURAL SPRING FROM DELTA OF MIDDLE ROUGE.

B. SPRING OF U. S. FISH HATCHERY, NORTHVILLE.

A. SWAN WELL, GROSSE ISLE, IN 1907.

B. SWAN WELL, GROSSE ISLE, AFTER SEVEN YEARS OF FLOW. CEMENT CURBING DESTROYED BY FROST.

A. STRATIFIED LAKE CLAY DEPOSIT, SPRINGWELLS TOWNSHIP.

B. PORTION OF SIBLEY QUARRY, CRUSHER AND LIME KILNS.

appear to lie in the high morainic regions to the west and north, as shown from the general diminution of head toward the south and east (see Pl. XXV). In a strip of territory extending northeastward from southern Canton and northeastern Van Buren townships, many of the deeper wells give much salt, which presumably is received from the underlying bedrock. A few data are here given concerning three of the most striking. It is likely that the Barker wells penetrated the Antrim shale without the driller knowing he had entered bedrock.

The well of C. F. Bevernitz, NW. 1/4 sec. 12, Nankin township, is 60 to 70 feet deep, the Antrim shale lying at a depth of 70 to 80 feet. The elevation of the mouth is approximately 635 feet. The supply is good, but there is too much salt in the water to permit its use; a tobacco pail full is said to have yielded, on evaporation, a pint of salt. There has been some gas in the well. The water lacks only 4 feet of reaching the surface, its actual head being about 631 feet.

Edward Barker, NE. 1/4 sec. 27, Canton township, has two wells, which were sunk to a depth of 108 feet in 1901. The Antrim shale is supposed to be from 100 to 110 feet from the surface. The approximate elevation of the mouth of the well is 657 feet and the head is —12 feet, giving the water level an elevation of 645 feet. Salt water was secured from near the bottom, 6 to 7 quarts yielding a teacup of salt. This water has been used for preserving pork and for killing thistles. The well was plugged below to shut off this supply and fresh water was used from a higher level in the well.

W. A. Wallace, SE. 1/4 sec. 32, Canton township, has a bored well 70 feet deep. The Antrim shale lies at 80 to 90 feet. The elevation of the well mouth is 695 feet and of the water surface 687 feet. The water is secured from just over hardpan and is hard and salty, too much so to drink, but may be used for other household purposes. Cattle will drink it and require no other salt.

Some of these mineralized waters not so highly charged with salt are being put on the market for their medicinal properties and sold in Detroit by the gallon. One of these sources of supply is on the Rouge flats at Plymouth. It is owned by Dr. M. V. B. Saunders, of Detroit, and is advertised as the "Plymouth Rock Mineral Well." The depth is 74 feet, the first 25 feet of which were dug and the remainder drilled. The elevation of the mouth of the well is about 700 feet, and, as the rock surface here is believed

to be from 630 to 640 feet, it is likely that the well penetrated the Coldwater shales. The water was said to have been secured from beneath an exceedingly hard 18-inch stratum. It is reported that 3,000 gallons are sold annually, and that it has been found especially efficacious in cases of rheumatism, kidney and bladder troubles. The following analysis, taken from the advertising circular, was made by Prof. John E. Clark, M. D., of the Detroit College of Medicine:

TABLE LI. ANALYSIS OF PLYMOUTH ROCK MINERAL WATER.

(Parts per million).

Potassium (K)	11.58
Silica (SiO_2)	8.57
Iron and alumina (Fe_2O_3; Al_2O_3)	29.76
Chlorine (Cl)	149.43
Sodium (Na)	124.01
Sulphate radical (SO_4)	4.31
Carbonate radical (CO_3)	192.95
Calcium (Ca)	24.22
Magnesium (Mg)	14.36
Organic and volatile	22.25

Carbonic-acid gas and carbonate of lithium present, but not estimated. A similar well near the above is owned by H. P. Peters and has a depth of 80 feet, possibly also reaching bedrock. The water is said to have originally flowed, and has been put on the market as "Hydrocarbon Mineral Water." Bubbles of gas, apparently carbon dioxide, are continually rising to the surface.

Flowing wells. When the head or pressure with which these waters enter the wells is sufficient, the water reaches the well mouth and overflows. Three disconnected belts of such flowing wells cross Wayne County, being the continuation of similar belts in Monroe and Washtenaw counties. One of these belts begins in the northwestern part of Van Buren township (secs. 3, 4, 5 and 6), extends northward across Canton, with a breadth of 2 to 3 miles, reaches into sec. 34 of Plymouth, and continues into the western part of Livonia township. The belt is not continuous, and all of the wells that are still flowing lie to the east of the gravel ridge formed by the waters of glacial Lake Whittlesey and known as the Whittlesey beach. This is due to the fact that the water does not have sufficient pressure to reach the level of this beach, which is about 740 feet above sea level. The artesian head in Wayne

County ranges from 680 feet above sea level to about 730, but farther north in Farmington township, Oakland County, rises to 760 feet. A second belt of flowing wells, artesian head 580 to 600 feet, lies in the eastern part of the county, extending from the vicinity of Flat Rock northeastward through Brownstown, Ecorse and Taylor, into Springwells, where it is interrupted by the Detroit moraine. In the northeastern part of Grosse Point township, the belt again appears and continues along the lake shore into Macomb County. It is this belt, especially that portion of it near the Huron, that has suffered great loss of head and volume. Between these two lies the third belt entering Huron township from Exeter and Ash townships of Monroe County although most of the wells have ceased to flow during the past decade. In looking northward for the continuation of this middle belt there is some doubt as to its course. Probably the area immediately to the west and north of Wayne continuing northeastward into Redford, across northwestern Dearborn, should be connected with those in the Willow-Waltz district, although the head is some 20 feet higher about Wayne and we should expect the belt to have a more northeasterly course.

The average temperature of the wells of the county as measured in May and June, is 52° F., or slightly less, but some show a rise of 1° to 3° in the fall, owing to the effect of the summer heat on pipes through which they slowly discharge. It is probable that if the bottom temperature were taken it would be found to be more constant, especially in the case of the deeper wells and wells with a weak flow. In these, the waters are either warmed or cooled as they approach the surface, except at times of year when the surface temperature corresponds closely with the temperature of the bottom of the well.

To the farmers, these wells are a great saving in time and expense of pumping (see Pl. XXVII, A and B) while the low summer temperature and constant flow are of great service in caring for milk in the dairy. The tanks do not ordinarily freeze over in winter and are thus available for the stock. The wells are about equally divided between hard and soft water, some of unusual softness occurring at Dentons, where they take the place of cistern water.

The two following partial analyses, furnished by M. O. Leighton, of the United States Geological Survey, show the relative composition of drift and rock waters at Dearborn:

TABLE LII. PARTIAL ANALYSES OF DRIFT AND ROCK WATERS AT DEARBORN.

(Parts per million).

	1.	2.
Color	32	32
Iron (Fe)	Trace	2
Chlorine (Cl)	19	15
Carbon dioxide (CO_2)	87.94	97.61
Sulphur trioxide (SO_3)	86	522

S. J. Lewis, analyst. 1. A. Wagner; depth, 28 feet. 2. A. Wagner (rock); depth, 115 feet.

These waters are said to produce only a very little scale in the tea kettle, even after several years' use. Simple tests show slight traces of salt, iron, and lime carbonate, but no lime sulphates, or but a trace. This condition of the water may be due in part to continuous leaching, the result of which would be to change flowing wells from hard to soft. The breaking in of new veins might, however, suddenly change the water from soft to hard. The water in the eastern belt is almost invariable charged with either iron or sulphur, along with the other minerals commonly present, owing to the nearness of bedrock. The pressure is generally low and sufficient only to elevate the water a few feet above ground level, but is somewhat greater in the western district. In the Penny well, sec. 3, Canton township, there is a strong flow which will rise 12 feet, thus having an elevation of about 727 feet above sea level. Most other wells in the western part of this belt indicate an artesian head of 710 to 720 feet, which, as a rule, drops to the southeast more rapidly than does the surface slope of the land, ranging from 6 to 12 feet to the mile within the belt. Most of the flowing wells in the eastern belt are from the bedrock, and thus belong to the class next to be described. The similarity in the character of the water would indicate that the western wells derive their supply and head from the same source, and hence that the eastern and western belts of flowing wells are genetically distinct, the western coming from the drift to the north and west and the eastern from bedrock. Table LIII shows the chief characteristics of this group of wells.

TABLE LIII.—FLOWING WELLS IN DRIFT, WAYNE COUNTY.

Township S.	Range E.	Section.	Quarter.	Township.	Owner.	Depth.	Quality.	Temperature.	Size of flow.	Head. Maximum.	Head. Present.	Elevation.	Remarks.
						Feet.		°F.	Inches.	Feet.	Feet.	Feet.	
1	8	34	NW	Plymouth	S. Bennett	70	Soft	51	[illegible]		0.7	720	Small amount of salt.
2	8	3	NW	Canton	O. F. Penny	86	Hard	51.5	[illegible]	+12	3	715	Will flow a 2-inch stream.
2	8	4	NE	Canton	E. Everett	35	Hard	51.5	[illegible]	+5	2.5	708	Some salt.
2	8	8	NE	Canton	G. S. Bonsteel	28	Soft	52	[illegible]	+8	3	711	Has flowed 3.5-inch stream.
2	8	8	SE	Canton	H. O. Hanford	30–35			[illegible]	+2.5		708	Strong in iron.
2	8	9	NW	Canton	Mrs. D. Schrader	50–60	Hard	60	[illegible]	+2	2	708	Waters 75 head of cattle.
2	8	9	NW	Canton	J. Quartle	28	Soft		[illegible]	+9	3	711	Made in 1868; contains salt.
2	8	31	NW	Canton	S. Goddell	70	Soft	50	[illegible]	+4	2	715	Used in dairy and laundry.
2	8	30	SE	Canton	J. Smith Estate	50–60	Soft		[illegible]	+2		689	Free from iron.
2	8	32	SE	Canton	J. F. Duntley		Soft	51	[illegible]		2	692	Used in dairy.
2	8	33	SE	Canton	J. E. Betts	30	Hard	51			1	685	Not affected by drought.
2	8	33	SE	Canton	G. Kissane		Hard	55	[illegible]		1.5	686	Running 15 years.
3	8	4	NW	Van Buren	J. Couch	63		53	[illegible]		3	696	Used in dairy.
3	8	4	NW	Van Buren	W. Deyo	42		51	[illegible]		2	693	Once flowed 49 gallons a minute.
3	8	4	NE	Van Buren	A. Kruger	75	Soft	51.5	[illegible]		3	690	Used in laundry.
3	8	4	NE	Van Buren	C. Nass	70		52	[illegible]		2	690	
3	8	4	NE	Van Buren	A. Gunther	72		50		+4		688	Running 14 years.
3	8	5	SE	Van Buren	W. H. Burrell	70	Soft	51	[illegible]		3	698	Used in laundry.
3	8	5	SE	Van Buren	F. Van Tassel	48	Hard		[illegible]	+12	4	696	Has flowed 1.5-inch stream.
3	8	6	NE	Van Buren	I. Glass	76	Soft	51	[illegible]	+2.5		705	Used in laundry.
3	8	6	NE	Van Buren	C. Shlicht	72	Soft		[illegible]		1	706	Denton village.
1	9	18	SE	Livonia	W. Hake	50	Medium	51			1	690	Would flow 1-inch stream.
1	9	17	SW	Livonia	R. L. Alexander	45	Hard	50.5	[illegible]	+4	2.5	693	From gravel over bedrock.
1	9	19	NE	Livonia	O. Melow	55	Soft		[illegible]	+12	1	680	Has flowed 2.5-inch stream.
2	11	18	SE	Springwells	Detroit Brick Co.	80	Hard	51	1[illegible]		4	590	Flows 90 barrels a day.
2	11	20	NW	Springwells	L. Maples	67.5	Hard	52	[illegible]		3	595	Strong in sulphur.
3	11	14	SE	Ecorse	J. Porout	78			Trickle	+4	.5	599	Contains sulphur.
5	10	5	SE	Ecorse	R. Smithson	28		51	1	+25		588	Iron but no sulphur.

The village of Wayne recently purchased five acres of the Kissane property, near the center of sec. 33, Canton township, and put in a test well to the depth of 120 feet, without reaching rock. A heavy vein of water was struck in a gravel stratum at a depth of 63 feet and a flowing well secured. The water is of medium hardness and shows no especial mineral substance. The pumping test conducted by Riggs and Sherman, engineers of Toledo, indicated an available daily supply from this one well of 150,000 gallons.

The following partial analysis of an unusually soft water from the parsonage well (depth 75 feet) near Denton, in the western part of the county, has been furnished by M. O. Leighton of the United States Geological Survey. The water tested is one of the softest in the state.

TABLE LIV. PARTIAL ANALYSIS OF WELL WATER AT DENTON.

	Parts per million.
Color	10
Iron (Fe)	Trace
Chlorine (Cl)	8.75
Carbon dioxide (CO_2)	97.61
Sulphur trioxide (SO_3)	.29 (?)
Hardness	56.1

The following partial analysis of the well water at the Commercial Hotel at Wayne is furnished by M. O. Leighton, of the United States Geological Survey.

TABLE LV. PARTIAL ANALYSIS OF WELL WATER AT COMMERCIAL HOTEL, WAYNE.

	Parts per million.
Color	19
Iron (Fe)	Trace
Chlorine (Cl)	15
Carbon dioxide (CO_2)	99.81
Sulphur trioxide (SO_3)	88

S. J. Lewis, analyst. Depth of well, 14 feet.

Boiling springs. The western half of Plymouth and nearly the whole of Northville townships are covered with ridges and knolls of till, interpersed with similar masses of stratified gravel and sand, giving a very rough aspect to the country. The features are those of a moraine formed at the ice margin during a temporary

halt in its general eastward retreat. The glacial lake waters subsequently covered the lower knolls lying to the east, but elsewhere the original roughness left by the ice has been very largely retained. Securing water from these clay knolls and ridges by means of wells is as difficult and uncertain as on the clay plains to the east and at times becomes impossible. The deposits of sand and gravel, however, serve as reservoirs for water, and, owing to their extent and height to the north and west, frequently yield large quantities under pressure. Along the hill slopes and in the valleys heavy natural flows occur, giving rise to what are known as "bold" or "boiling" springs. They differ from the seepage springs in that they have "head," and a generally stronger flow, are subject to less variation, show a steadier temperature, and yield a harder water. In numerous cases, the waters are piped to dwellings and barns and yield an ideal supply, as on the Starkweather place in the southwest part of Northville township, where a spring located in the NW. ¼ sec. 8, is piped to the house, having a fall of 16 feet, delivering a 1-inch stream and keeping 5 troughs supplied with most excellent water for stock. This water contains considerable calcium carbonate, a very little salt, and gives no reaction for calcium sulphate.

Two similar springs are utilized by the United States fish hatchery at Northville (Pl. XXVIII, B). After cleaning in 1896, the flow from the large spring was somewhat more than 500 gallons a minute, but has been gradually declining since. In the fall of 1904, a second cleaning failed to increase the flow much. According to the earlier reports, the temperature was 47° F., but is now 48°, with only slight variation from season to season. This is the coldest water observed in any part of the county. It is rendered hard by considerable calcium carbonate, but gives no reaction for salt or gypsum. Immediately beneath the hatchery building is a second spring which has yielded 136 gallons a minute and has a temperature of 48°. There are two flowing wells having a depth of 106 feet, which yield 1½ and 2 gallons a minute, with a temperature of 50°, but the water contains sulphur and iron and is destructive to both eggs and fish.

The villages of Northville and Plymouth are favorably situated for utilizing similar flows from springs sufficiently elevated to give the necessary pressure without pumping. The water is cold and pure; is rendered hard by calcium carbonate; gives no reaction for gypsum, and only a slight one for salt. The supply is sufficient except during times of prolonged drought. The water is not metered and no estimates are kept of the amount used. Neither

of the villages is supplied with sewers, the drainage being good in both cases. The plants are owned and operated by the villages themselves. Northville, with a population of 1665 draws its supply from two springs in Oakland County, about 4 miles distant. The springs are about 1,000 feet apart and empty into a small receiving basin, from which the water flows by gravity, with slight fall, to a reservoir overlooking the village and 100 feet above it. The village of Plymouth, with a population of 1671 has a system similar to that of Northville, its springs being in the NE. 1/4 sec. 8, Northville township, in the bottom of an old drainage channel from the ice sheet. The village has here purchased an acre of land on which an excavation 50 by 60 by 6 feet has been made, lined with cobble, and surrounded by a high wire fence. From this the water flows by gravity to a reservoir, which is located 2 miles from the village and 103 feet above it. Both of these villages made the mistake of first putting in vitrified crock instead of iron piping and this had to be replaced with the latter at great expense.

WATERS FROM THE BEDROCK.

Geological formations. Beneath the mantle of clay, sand, and gravel, resulting from the joint action of wind, water and ice, there lies a series of stratified rocks, consisting of sandstone, shale, limestone and dolomite (see Pl. XXV). These have been described in detail in Chapter VI of this report and only a brief summary need be given here. Formed in the sea, in approximately horizontal layers, they were early upheaved and tilted, so that their edges have a general northeast trend in Wayne County, and the beds themselves dip to the northwest at the rate of some 25 feet to the mile. They still retain some of the minerals belonging to the concentrated brines of the primitive seas, and others deposited at the time the rocks were forming, or subsequently. These beds supply a limited part of the county with a more or less highly mineralized water, much of which flows, but some of which must be pumped. The youngest and highest of this series of beds in Wayne County cuts across the northwest corner. It consists of shales, with some sandstone, and is known in the state as the Coldwater shale (Waverly and Cuyahoga). Beneath this lies the dark Antrim shale (Genesee), generally yielding gas and faint traces of oil. Next in order come the bluish beds of shale and limestone, making up the Traverse group (Hamilton), and frequently referred to as "soapstone;" beneath which lies a solid, light-gray limestone

known in the state as the Dundee (Onondaga). Below this limestone is a drab dolomite, the Monroe group ("Lower Helderberg"), which drillers do not ordinarily separate from the preceding. Embedded in it and of the same geologic age is the so-called Sylvania sandstone, a pure glass sand, cutting across the extreme southeastern part of the county; this is the oldest of the formations reached directly beneath the clay in the county. Still older and lower, however, and coming near the surface in Monroe County and bordering parts of Ohio, lie, in order, the Monroe beds below the Sylvania sandstone, the Salina, Niagara, Medina, Hudson, Utica and Trenton, the last being the oldest bed reached by borings in the county.

Flowing wells. The wells of this class comprise most of those in the eastern belt described above. They are heavily mineralized, as a rule, and frequently rendered rank by sulphur and iron. The average temperature is 51.4°, as compared with 52° for the flowing drift wells, but rises slowly as the water comes from greater depth. Theoretically the temperature should be still more constant than in the drift wells, but it must be affected in the same way and to the same extent as it rises to the surface. With reference to the level of the ground the head is generally slight, ranging from a mere rise to the surface to 15 and 25 feet above in exceptional cases. At Dentons, in a well along the railroad track, the water is reported to have reached the second story of a building, indicating its rise to about 715 feet above sea level. The Swan well on Grosse Isle is the easternmost of the flowing wells in the county and has a head of 597 feet. Measured between these two extreme wells, the average reduction in head toward the southeast is 5.6 feet to the mile. Between the Flat Rock wells and those on the lake shore, the average reduction per mile is 3.5 feet. Although the rock strata are dipping to the northwest, these facts indicate that the source of supply is to the west, as pointed out by Fuller in his report on the failure of wells along lower Huron River (p. 37). In his investigation of the wells of this region, he found the average reduction in head of the wells about the Swan Creek-Rockwood district to be about 3 feet per mile to the eastward.

Table LVI gives the principal data concerning the flowing wells from bedrock. The most wonderful of the entire set is the Swan well described by Fuller (pp. 43-44), which flows 3,000 gallons a minute, or 4,320,000 gallons a day—enough to supply several times over the entire river front from Trenton to Detroit.

The following analysis shows the composition of this water.

TABLE LVI. ANALYSIS OF WATER FROM JAMES SWAN'S WELL ON GROSSE ISLE.

(*Parts per million*).

F. K. Ovitz, Ann Arbor, analyst, Jan., 1905.

Silica (SiO_2)	188.00
Iron and alumina (Fe_2O_3, Al_2O_3)	14.00
Calcium (Ca)	5,082.96
Strontium (Sr)	317.00
Magnesium (Mg)	730.57
Sodium (Na)	216.78
Potassium (K)	79.68
Sulphate radical (SO_4)	14,245.21
Carbonate radical (CO_3)	871.35
	21,745.55

It was the original intention of the owner to market the water under the trade name "Kathairo" but this was done for but a short time. When the water is fresh, there is a pronounced flavor of sulphur which does not appear in the above analysis. In 1905 a strong flow of sulphur water (temperature 52.3°F.) was struck at Dearborn, upon the River Rouge flats (NE. 1/4 NE. 1/4 sec. 21), at a depth of 108 feet and penetrated 182 feet, the water rising to a height of some 30 feet above the mouth of the well in the casing, and indicating a head of 635 to 640 feet above sea level. The well is capped but the casing is leaking and indicates no loss in pressure, suggesting that the flow is truly hydrostatic and not due to gas pressure as originally supposed.

TABLE LVII.—FLOWING WELLS FROM BEDROCK, WAYNE COUNTY.

Township S.	Range E.	Section.	Quarter.	Township.	Owner.	Depth.	Geologic horizon.	Character of water.	Approximate elevation.	Diameter of discharge pipe.	Temperature.	Depth of rock.	Remarks.
						Feet.			Feet.	Inch.	°F.	Feet.	
3	8	6	NE	Van Buren	Bandy	125	Coldwater	Soft	705	......	......	81	Village of Denton.
2	8	28	NE	Canton	M. Carleton	140	Antrim	Salt and iron	682	(a)	......	70	Gas; not usable.
2	11	18	SW	Springwells	A. Lapham	129	Traverse	Hard	588	1/2	52	100	Recently ceased flowing.
3	10	34	SW	Taylor	J. Shetrum	86	Corniferous (b)	Sulphury	603	......	......	83	Now rises 4 feet.
2	11	4	SW	Springwells	J. C. McDonald	250	Corniferous	Hard	605	3/4	53	125	Rank in iron and sulphur.
3	11	30	SW	Ecorse	Beaubien	64	Corniferous	Hard	587	1/2	51	64	Strongly mineralised.
3	10	35	NE	Ecorse	Unger	......	Corniferous	Hard	598	1/2	51	......	Minerals abundant.
4	10	13	SE	Monguagon	Duman	30	Corniferous	Hard	580	1/2	52	2	Strongly mineralised.
4	10	25	NW	Monguagon	E. Lathrop	12	Corniferous	Sulphury	578	3/4	......	10	......
4	10	3	NE	Brownstown	Clark	68	Corniferous	Hard	597	3/8	51	......	Mineralized.
4	10	3	NW	Brownstown	G. McDonald	76	Corniferous	Hard	602	1/2	52	76	......
4	10	4	NE	Brownstown	J. G. Carson	65	Corniferous	Hard	603	3/4	51	......	Strongly mineralised.
2	10	1	SW	Dearborn	W. Robertson	357	Monroe	Hard	611	1/2	52	100	Rank in sulphur.
2	11	......	......	Ecorse	Detroit Salt Co.	1,096	Monroe	Sulphur	582	......	......	95	Sulphur water at 223 feet.
2	11	......	......	Ecorse	Brownlee & Co.	1,200	Monroe	Sulphur	578	......	......	82	Strong sulphur vein at 168 feet.
2	10	21	NE	Dearborn	Dr. T. V. Law	290	Monroe	Sulphur	605	8	......	108	Head 635 to 640 ft.
5	10	8	NE	Brownstown	B. Hall, Sr.	......	Monroe	Hard	587	3/4	51	......	Iron and sulphur; little salt.
5	10	9	NW	Brownstown	E. T. Wood	22	Monroe	Hard	587	3/4	55	22	Iron and sulphur; little salt.
5	11	......	......	Grosse Isle	J. Swan	2,375	Trenton	See analysis	575	13	52	17	Flows 50 gallons a second; head 597 feet.

(a) Trickle. (b) Corniferous (Dundee.)

The deep wells about the mouth of the Rouge will flow if permitted to do so, giving a type of water strongly mineralized and rank in sulphur. Two samples of such water from the Oakwood salt shaft have been analyzed in the laboratory of the Bureau of Mines, Department of the Interior, Washington. The first is of the cold water as it comes from the rock, before it has had an opportunity to become heated by mingling with the steam. The second analysis is of the hot water as it flows from the pipe at the mouth of the shaft. The depth of the first sample is not given, probably between 480 and 533 feet, the latter depth being the greatest at which water now enters.

TABLE LVIII. ANALYSIS OF WATER FROM OAKWOOD SALT SHAFT.

Analyst A. C. Fieldner, Bureau of Mines.

(Parts per million).

	Cold.	Hot.
Total solids at 105°C.	4785	9520
Loss on ignition	389	933
Silica (SiO_2)	16	14
Alumina (Al)	5	9
Iron (Fe)	3	9
Calcium (Ca)	727	927
Magnesium (Mg)	217	310
Sodium (Na, as alkali)	502	1848
Sulphate radical (SO_4)	1990	1937
Chlorine (Cl)	1117	3880
Hydrogen sulphide (H_2S)	249	43

The head of the combined flows here was found to equal 20 feet above the surface, or about 595 feet above sea level. By the time 420 feet of depth was secured, the total flow into the shaft was estimated by the engineer, Mr. Eugene Bradt, as 2,000,000 gallons a minute, or about 1-47 of that of Detroit River. A more detailed description of the various veins encountered in this remarkable undertaking will be found in the chapter following. Compared with the water of the Swan well, the salt shaft water is seen to be less heavily mineralized. This may be due to the partial leaching of the neighboring strata in consequence of the excessive flow from them during the past five years. The first heavy flow in the Swan well was encountered at 420 feet and a still heavier one at 450, corresponding very closely to that of the salt shaft. The head of

the water in the two cases is so nearly the same (595 and 597) that a close connection between the veins may be inferred. In passing northwestward towards Dearborn, the head rises to 635 or 640 feet, a gain of 40 to 45 feet, or somewhat less than 8 feet to the mile, the water being encountered some 160 feet higher in the rock series. Whether we assume that these two flows are connected, or not, we must look to the northwestward for their source, the most probable collecting area being the high morainic strip of country passing NE.-SW. across Washtenaw and Oakland counties. The rock surface here rises from 700 to 800 feet, above sea level, and reaches 900 feet in western Washtenaw and Livingston counties.[8] The water may be assumed to find its way through the drift cover to bedrock, entering through joints and fissures, and working its way to lower levels across the strata, dissolving minerals en route, is ready to escape under great hydraulic pressure whenever an artificial opening is afforded. Not being confined to a single, pervious rock stratum, as is generally the case, makes the obtaining of such artesian flows at any given point a decidedly uncertain matter.

At the plant of the Murphy Power and Ice Co., corner Wayne and Congress streets, Detroit, four wells have recently been put in to a depth of 275 to 300 feet. Rock was struck at about 100 to 110 feet (about 490 feet above sea level), from which a flow of sulphur water was obtained. A much heavier vein was reached at a depth in the limerock (dolomite) of 170 to 200 feet, rising to within about 15 feet of the surface, where the elevation is about 595 feet above sea level, thus showing 580 feet as its head. Tests relative to the amount of flow from the wells indicated a possible 1000 to 1200 gallons per minute. The temperature of the water is 52°F., especially adapting it to use in the condensers.

Springs. In the Brownstown region of flowing wells, there are numerous natural flows charged with iron, sulphur, calcium sulphate, calcium carbonate, and sometimes considerable salt. These are most numerous along Huron River, from Flat Rock to Lake Erie and northward to Gibraltar. The water is generally too rank for use and is believed to come from bedrock, having made for itself a natural channel through the clay. Such springs are found in Brownstown as follows:

T. 4 S., R. 10 E.; NE. 1/4 sec. 28, SW. 1/4 sec. 30, SE. 1/4 sec. 31, NE. 1/4 sec. 36.

T. 5 S., R. 10 E.; SW. 1/4 sec. 5, NE. 1/4 sec. 9, SE. 1/4 sec. 13, NW. 1/4 sec. 1, eastern and southern portions of sec. 24.

8. Geological Survey of Michigan, Report for 1907, plate VI. Also Water-Supply Paper 183, plate II, U. S. Geological Survey.

TABLE LX. ANALYSIS OF WATER FROM SALT WELL, WAYNE COUNTY INFIRMARY, ELOISE.[11]

	Parts per million.
Calcium (Ca)	9,714.65
Carbonate radical (CO_3)	3,970.25
Magnesium (Mg)	150.17
Sulphate radical (SO_4)	12,354.88
Chlorine (Cl)	40,214.11
Sodium (Na)	25,354.54
Total solids	91,758.60
Hydrogen sulphide	405.00

These highly charged mineral waters are used for bathing purposes at two places in Detroit—the Clark Riverside Bath House and the Detroit Mineral Bath Co. Along Detroit River from Delray to Trenton, artificial brines are made by forcing water to the salt beds of the Salina series, where they dissolve the solid rock salt and flow to the surface. The salt is then secured by evaporation or used in the manufacture of soda, soda ash, and bleaching powder. The most promising horizon for securing a supply of fresh water is the Sylvania sandstone, a porous bed of pure sandrock holding an abundance of water. Although fresh, it is liable to contain sulphur and iron, carried up from the dolomites of the underlying Monroe group. In the northern part of Monroe County and the southern part of Brownstown township, this bed lies immediately beneath the clay and furnishes an abundance of good water. In the 7 miles to Trenton it drops to 280 feet below the surface, or at the rate of about 40 feet to the mile. Toward Wyandotte the bed thickens, with practically no dip, and in the Eureka well it was reached at 230 feet, while in a well of the Michigan Rock Salt Company, at Ecorse, it was reached at 220 feet. Beyond Ecorse, it drops rather rapidly again, having an average thickness of 99 feet in ten wells of the Solvay Company at Delray.

WATER DECLINE IN LOWER HURON REGION.

Facts relative to decline. During the past twenty years, or more, a marked decline in the volume and head of the well water of the lower Huron region has been in progress, causing great annoyance and much expense to the farmers of the localities involved. This is in striking contrast with the belt of flowing wells in the western

11. Expressed by analyst in hypothetical combinations; recomputed to ionic form at United States Geological Survey.

part of Wayne County where the only reduction observed may be reasonably ascribed to accumulation of sand and defective casing; difficulties that are rather easily remedied. In the lower Huron region, however, from the vicinity of New Boston to Lake Erie, the wells appear to have been flowing too near the level of their head and, over a strip 5 to 6 miles broad, upon either side of the river, have virtually ceased to flow. The loss of head during the past ten years averages from 5 to 10 feet and, in regions where flowing wells could be counted by hundreds, scarcely a one remains (see Pl. XXV). To the south of the Huron in Monroe County a careful survey of the flowing well districts, made during the summer of 1911, revealed the fact that not a single well now reaches the general surface and but five still remain flowing upon flats from 3 to 5 feet below the general level. North of the river, very exceptionally a genuine flowing well may still be found, but giving only a greatly reduced flow under low head. The wooden casing projecting above ground with its succession of holes tells the pathetic story. Although the decline has been continuous over a long period it does not appear to have been gradual. A very marked reduction occurred in 1904 and led to an investigation of the probable causes by Myron L. Fuller, of the U. S. States Geological Survey.[12]

Fuller's investigation. The data gathered for this report were obtained in the main from Monroe County, adjacent to the Huron, the region north of the river, between Rockwood and Detroit River, then showing comparatively little shortage. Since then, however, every well in this section upon the general level has ceased to flow, some of them as late as August, 1911. Evidently the causes are still operative and before discussing what these appear to the writer to be, it will be of interest to the reader to learn the conclusions of Fuller as presented in his report.

"The general decline which has been going on for many years is probably due to a gradual and far-reaching change of conditions, such as deforesting of the land, improvement in surface drainage, etc., but the rapid decline of the last two seasons is doubtless due to local causes acting with special force in the region in question."

Grosse Isle well.—"That the Grosse Isle well (see Pl. XXIX, A and B) is the cause of the special decline in 1903 and 1904 may at first thought seem well sustained by the behavior of certain wells, as J. E. Brown's of the Swan Creek and Charles Bancroft's

12. See Water Supplies of the Lower Huron River Region. Flowing Wells and Municipal Water Supplies in the Southern Portion of the Southern Peninsula of Michigan, 1906, p. 33. Water-supply and Irrigation Paper No. 182, U. S. Geological Survey, Washington, D. C. Also Geological Survey of Michigan, Annual Report for 1904, p. 7.

TABLE LX. ANALYSIS OF WATER FROM SALT WELL, WAYNE COUNTY INFIRMARY, ELOISE.[11]

	Parts per million.
Calcium (Ca)	9,714.65
Carbonate radical (CO_3)	3,970.25
Magnesium (Mg)	150.17
Sulphate radical (SO_4)	12,354.88
Chlorine (Cl)	40,214.11
Sodium (Na)	25,354.54
Total solids	91,758.60
Hydrogen sulphide	405.00

These highly charged mineral waters are used for bathing purposes at two places in Detroit—the Clark Riverside Bath House and the Detroit Mineral Bath Co. Along Detroit River from Delray to Trenton, artificial brines are made by forcing water to the salt beds of the Salina series, where they dissolve the solid rock salt and flow to the surface. The salt is then secured by evaporation or used in the manufacture of soda, soda ash, and bleaching powder. The most promising horizon for securing a supply of fresh water is the Sylvania sandstone, a porous bed of pure sandrock holding an abundance of water. Although fresh, it is liable to contain sulphur and iron, carried up from the dolomites of the underlying Monroe group. In the northern part of Monroe County and the southern part of Brownstown township, this bed lies immediately beneath the clay and furnishes an abundance of good water. In the 7 miles to Trenton it drops to 280 feet below the surface, or at the rate of about 40 feet to the mile. Toward Wyandotte the bed thickens, with practically no dip, and in the Eureka well it was reached at 230 feet, while in a well of the Michigan Rock Salt Company, at Ecorse, it was reached at 220 feet. Beyond Ecorse, it drops rather rapidly again, having an average thickness of 99 feet in ten wells of the Solvay Company at Delray.

WATER DECLINE IN LOWER HURON REGION.

Facts relative to decline. During the past twenty years, or more, a marked decline in the volume and head of the well water of the lower Huron region has been in progress, causing great annoyance and much expense to the farmers of the localities involved. This is in striking contrast with the belt of flowing wells in the western

11. Expressed by analyst in hypothetical combinations; recomputed to ionic form at United States Geological Survey.

part of Wayne County where the only reduction observed may be reasonably ascribed to accumulation of sand and defective casing; difficulties that are rather easily remedied. In the lower Huron region, however, from the vicinity of New Boston to Lake Erie, the wells appear to have been flowing too near the level of their head and, over a strip 5 to 6 miles broad, upon either side of the river, have virtually ceased to flow. The loss of head during the past ten years averages from 5 to 10 feet and, in regions where flowing wells could be counted by hundreds, scarcely a one remains (see Pl. XXV). To the south of the Huron in Monroe County a careful survey of the flowing well districts, made during the summer of 1911, revealed the fact that not a single well now reaches the general surface and but five still remain flowing upon flats from 3 to 5 feet below the general level. North of the river, very exceptionally a genuine flowing well may still be found, but giving only a greatly reduced flow under low head. The wooden casing projecting above ground with its succession of holes tells the pathetic story. Although the decline has been continuous over a long period it does not appear to have been gradual. A very marked reduction occurred in 1904 and led to an investigation of the probable causes by Myron L. Fuller, of the U. S. States Geological Survey.[12]

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of the Rockwood district, which went dry when the big flow of the Grosse Isle well first began in 1903, but returned soon after the insertion of the casing, only to cease again after its withdrawal in May, 1904. This interpretation, however, seems opposed by the fact that numerous other wells much nearer Grosse Isle maintained nearly their usual flow, those nearest, even those on Grosse Isle itself, showing no decrease whatever. The conditions of underground drainage would need to be very exceptional, which would leave a nearby district unharmed while seriously affecting more remote districts, and belief in them would need be supported by indisputable evidence in the altered slope of the water table. In order to obtain light on this point the height to which water will rise was platted for each well in the Swan Creek-Rockwood region. It was found that this height showed an increase westward which averaged about 3 feet to the mile, indicating a source from that direction. The increase of head to the west or decrease to the east was found to be quite regular, with no local lowering or reversed slope that could be referred to a strong intake at a particular place. It was also found that the water level of the Grosse Isle gusher is higher than that of the shallow wells around it, and even higher than that of the wells of the Rockwood and eastern portion of the Swan Creek area, being 25 feet above the lake, or 597 feet above the sea, while the normal level in many of the wells which have been thought to feed it is several feet lower, in some of them being less than 590 feet. It would appear, therefore, that if any connection exists between the Grosse Isle well and the shallow wells in the Rockwood and Swan Creek areas the water would be forced up in the shallow wells rather than drawn away from them. The failure of such wells as the Brown and the Bancroft flows in 1903 was probably a mere coincidence. The precise point where the main water-bearing bed of the Grosse Isle well outcrops and takes in its main supply can not be stated. On the basis of the dip of the rock formations from southeast to northwest, at the rate of about 20 feet a mile, it would seem probable that the bed struck at 450 feet in this well will come to the surface somewhere west of Leamington in Canada. The supply seems, therefore, more likely to come from the Canadian than the Michigan side of Detroit River.

Newport quarry.—The underdrainage caused by the quarry at Newport was, next to the Grosse Isle well, most commonly advanced as a cause of the shortage along Swan Creek. A visit was accordingly paid to the locality and the conditions were investigated. It was found that a few of the wells near at hand have been affected.

but the decrease in water supply is not universal even within a few hundred feet of the quarry. A quarter of a mile back no effect has been noted. From this it appears that the quarry can not be considered a factor in the shortage along Swan Creek or in the Rockwood region.

Low stage of streams.—The level of streams generally determines that of the ground water in their vicinity, the latter subsiding as the streams fall. During 1904 both Huron River and Swan Creek were unusually low, and thus drew unusual quantities from the surrounding water table, which was thereby naturally lowered. Huron River, being a longer stream, and one having its source in a region of greater rainfall, was not so low as Swan Creek, the entire course of which is within an area of low rainfall. Moreover, the latter, flowing over clay nearly destitute of water, receives in considerable portions of its course only slight additions by percolation. It is probably for these reasons that the shortage is most marked along its course rather than in any other part of the region.

Early winter of 1903.—This appears to have been an important factor in bringing on the present acute shortage. According to the official records, the permanent freezing of the ground took place on November 17, which was before heavy snows and heavy winter rains had fallen. There was, therefore, little chance for the rainfall to soak into the ground during the winter and early spring months. This was made manifest by the low water in many of the wells during the winter, the result being that when spring opened the ground water was at an unusually low stage.

CONCLUSIONS.

The low rainfall, which in the spring of 1904 varied from one-eighth to somewhat more than one-half of the usual amount at the stations in the tables, was, on the whole, even less in the lower Huron River region itself. The deficiency of rainfall, following as it did an autumn and winter during which little water was absorbed owing to the frozen condition of the ground, together with the preceding dry season of 1903, seems ample to explain much if not all of the observed shortage.

Although considerable rain fell in July, and even more than the normal in August, it came largely as short heavy showers, and the water, instead of soaking into the ground, as in more gentle rains, formed streams and ran off rapidly. The part that soaked into the ground was entirely insufficient to compensate for the many

dry months which had preceded, especially as the relatively wet months of August and September were followed by several months when almost no rain fell. In this connection it may be remarked that, while the shortage was felt in the region under discussion sooner than elsewhere, the drought became severe enough later in the summer to be felt through all the states bordering the Ohio and eastward to New England, causing much shortage in wells.

If, as seems probable, the failure of the well is due largely to the severe drought of 1903-4, the return to the normal rainfall should result in an increase in the water supply, although, because of the excessive dryness of the ground, the increase in the available water may not be immediately noted. The full supply may not return until a wet year, or perhaps a succession of wet years, occurs.

In some cases the return of the water may not bring restoration to the wells, for water passages in clayey material when dried out may, to a certain extent, crumble and become more or less clogged, so that their capacity for carrying water is lessened or destroyed even when the ground again becomes soaked. The return in any case will probably not be complete, as the thorough ditching which the region has undergone will result in a permanent lessening of the water supply of the region.

The wells in the lower Huron River region obtain their supplies largely in the upper few feet of the rock. The water, judging from its head, is derived from glacial deposits overlying the rock in the region northwest of the area under discussion. It probably traverses the upper more open and jointed portion of the rock, because there is less resistance to its flow through the crevices and openings in the rock than through the compact clayey deposits which so generally overlie the rock formations of the region. The rock formations appear, therefore, to take in the water from the overlying glacial deposits, and, as shown above, a deepening of the wells into the rock has generally met with at least partial success. The great majority of wells now are exceptionally shallow compared with those of large areas in Michigan, where depths of 100 to 150 feet or more are common. It seems probable that wells of such depths in the region under discussion would yield permanent and abundant supplies."

Present conditions. The exceptional climatic conditions of 1903-4 held responsible for the decline of the water in the above region have passed away but without furnishing any relief in the situation. So far as we may judge from the Detroit records, the amount

of precipitation in this section of the state has about held its own during the last decade. Deforestation, better drainage, cultivation of the soil over the collecting areas for this underground water, along with cycles of climatic change, may be expected to have operated equally upon the western belt of flowing wells and upon the northeastern extension of this same eastern belt. Not having done so, leads one to infer that some exceptional causes are operative in the lower Huron area. There is little doubt that the large number of flowing wells and springs opened in the district, with no attempt whatever to reduce their flow, would sooner or later, bring about a marked reduction in head. The effect should show itself first in the higher, western tract and gradually work its way toward the lake, near which we should expect to find some wells still flowing. That these have also ceased indicates, either that the collecting area has failed to receive the amount of water adequate to maintain the regular flow, or that the water is being drawn off at a lower level. In view of the facts stated above the former of these hypotheses may be eliminated from the discussion and we may consider any facts relative to the latter in our search for the probable cause of the water failure in this region. Our attention is thus directed to the quarries of the region, the Livingstone cut, the Grosse Isle flowing well and the Oakwood salt shaft, all of which are instrumental in abstracting the water from the deeper strata and delivering it at the surface.

Mr. Fuller has given good theoretic reasons for believing that the Grosse Isle well of James Swan could not be held responsible for the sharp decline which called forth his investigation. The farmers of the district were thoroughly convinced, however, from the behavior of their wells, that it was the immediate cause and made up a purse in 1904, which was used in bringing about a conference between Judge Swan and the supervisors of the townships interested. As a result of this conference, the farmers were asked to raise a fund of $500 for the purpose of reducing the flow of the well to a 4-inch stream, when, if it should appear that the well was really responsible for the loss of head upon the mainland, a gross sum or annuity, to be decided upon later, should be paid Mr. Swan. The proposition was not accepted by the farmers and the well is still discharging into Detroit River some 4,320,000 gallons daily, with no attempt at utilization. As to the possible connection between this well and the sudden decline in the wells at Flat Rock, Mr. Curtis L. Mettler, flour and lumber merchant, writes: "In the summer of 1903, Mr. Swan was boring a well on his farm,

supposedly for oil; and at about 400 feet below the surface, struck a vein of water. So strong was the flow, that he was obliged to case it in order to proceed drilling. During the time between the striking of the vein and getting the casing in place, many of the small flowing wells stopped running. When the casing was placed in the well, it cut off the flow of water, and all, or nearly all of the wells commenced flowing again. He continued drilling until the well was about 2200 feet deep, and gave it up, (in the summer of 1904) and drew the casing out, which allowed the water to run again. The wells on all the farms again ceased flowing, and are still dry" (Dated Nov. 15, 1911). The heavy flows of water referred to were struck at depths of 420 feet and 450 feet, consisting of fresh water, the sulphur being introduced from smaller flows at a greater depth. The casing was in position from August, 1903, to May, 1904. It might be urged that the response of the wells upon the mainland was too prompt, but with subterranean passages in the dolomitic strata perhaps this can not be urged against the explanation given.

From the Livingstone cut in the strata of the Detroit River bed, opposite Stony Island (see Pls. V, A and XXIV), there has been a very heavy pumpage, estimated by Supt. G. P. Locker at 12,000,000 gallons daily. Since the first steam shovel was started Oct. 27, 1908, the flow from strata has gradually increased and although some of this comes directly from the river, the presence of much sulphur and iron indicates that the bulk of it is directly from the rock, to a depth of 24 feet below the river level, or an actual elevation of 550 feet above sea level. Mr. George H. Cohoon, a well driller of Trenton, of many years' experience, is convinced that we have here the cause of the recent failure of wells in northern Brownstown and Monguagon townships. Before this report finds its way into print, the water will have been allowed to fill this cut and former conditions to some extent restored by water pressure. Mr. Fuller considered the possibility of the quarry at Newport being responsible for the shortage in that vicinity, but finding that the drainage into this amounted to but about 43,200 gallons daily and that some wells near at hand seemed to be unaffected, decided that this might be neglected. When, however, all of the quarries of the Detroit River region and the Oakwood salt shaft are considered together there seems much more probability that we may have here one of the efficient factors. An effort was made to collect as definite data as possible from those in charge of these industries relative to the average daily pumpage. In com-

bination with the loss of water from other sources, we have the following table which shows that the rock strata during the past three years have been losing *daily* between 17 and 18 millions of gallons, equal to the entire flow of Detroit River for *11 seconds.* Or to look at the matter differently, this quantity of water represents the probable absorption over 17 to 18 square miles of the collecting area. With these data before us there is little cause of surprise that the wells of the adjacent region should have lost a few feet of head.

TABLE LXI. ESTIMATED AVERAGE DAILY PUMPAGE.

Livingstone Channel cut	12,000,000 gallons.
Grosse Isle well	4,320,000 gallons.
Oakwood salt shaft	568,800 gallons.
Sibley quarry	350,000 gallons.
Anderdon quarry	150,000 gallons.
Gibraltar quarry (now filling)	144,000 gallons.
Rockwood sand pit (no estimate available).	
Newport quarry (now filled)	43,200 gallons.
Total	17,576,000 gallons.

Remedies. As to remedies there is something to be said although there may be little of practical value to be done. The Livingstone cut is now filled, the Patrick quarry upon Grosse Isle, the Gibraltar and Newport quarries have been abandoned and now stand full of water, the pressure of which will prevent loss from the strata. The shaft of the Oakwood salt shaft will be eventually completely jacketed with cement which will take care of the loss there. So long as there is no attempt made to utilize the flow from the Grosse Isle well, this should be securely confined. In this way, the loss will be reduced to 600,000 gallons daily, a very small percentage of what it has been during the past three years. In closing his report, as published in the Michigan Geological Report for 1904, Fuller calls attention to the desirability of legislation looking towards the control and conservation of this very important resource, the necessity for such legislation becoming more and more urgent each year (page 29).

"Ground water is properly a commodity belonging to the public at large, and is an asset of recognized value. The amount is not unlimited at any point, and any decrease in its volume means a reduction of assets and a permanent loss to the community. It is

difficult to prove damages to surrounding wells caused by free flows. but when it is remembered that the underground supply is limited in amount, and that the available supply is being constantly decreased by such flow, it is readily seen that the loss is none the less real. A freely flowing well is in itself a proof of such loss, and should be forbidden, except where reasonable use is made of it.

(1) An enactment should be passed making it unlawful to permit water to escape where no use is made of it regardless of the size of pipe or volume of flow, and a penalty should be fixed for its infraction.

(2) An enactment should be passed making it obligatory in case of abandoning a well over two inches in diameter to securely plug it above and below each water horizon, or to fill the hole with cement or other impervious material, with a penalty fixed for its infraction as before.

(3) An enactment should be passed requiring that wells, when not in use, shall be closed down until not more than an inch stream[13] is flowing, a penalty to be attached for its infraction as before.

(4) Provision should be made for restraint of flows by injunction on application of parties presenting evidence of waste.

(5) The power of entering private property for the purpose of determining questions relating to waste should be given to proper officials."

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13. The writer would make this a quarter-inch stream instead, or perhaps prescribe a certain measured flow per minute.

CHAPTER VIII.

ECONOMIC RESOURCES.[1]

MATERIALS USED IN CONSTRUCTION.

Clays. Although the bedrock of the county is covered with a heavy burden of glacial clay, the occurrence of pebbles more or less abundantly throughout the formation renders it unfit for the usual forms of manufacture. In certain sections, the percentage is relatively low and, by running the raw clay through a crusher, they may be reduced to powder, the rock fragments too coarse for the crusher being removed by hand. Another method for utilizing such clay is to place it in tanks where it may be disintegrated by water and the water, carrying the clay in suspension, allowed to flow into settling vats from which it may be recovered. The inconvenience and expense necessitated by either of these methods prevent their use until the purer grades of sedimentary clays have been exhausted in this region. As pointed out in Chapter III, these clays have already been subjected to this washing process in Nature's great laundry, resulting in the removal of the sand, gravel and boulders and the deposition of the clay along the river courses and over the beds of the extinct lakes. The most important of these deposits have been described in Chapter III of this report and their characteristics presented.

When subjected to the burning process, as in the manufacture of brick and tile, the clay loses its original color and assumes a pink, or pale red. The deeper red, commonly desired, is obtained in the case of the brick by dusting over them, before burning, pulverized iron oxide and in the case of the roofing tile a clay wash rich in iron. The paleness of the burned clay is not due to an insufficiency of iron in the clay itself but to its neutralization by the alkalies present, and is a positive advantage in the case of the roofing tile since this color serves as a better background for the ordinary glazes than a deep red would do. The shrinkage of the clay is ordinarily low and may be still further reduced by adding sand in small quantity, too much giving a porous product. Data

1. When the original data relative to the economic resources of Wayne County were collected in 1902-3, detailed statistics were obtained concerning the various industries. Since these are now out of date and the State Geological Survey has recently been assigned the duty of gathering such statistical data, the reader is referred to the Survey for such information.

relative to the air and fire shrinkage have been obtained by W. G. Worcester, formerly superintendent of the Detroit Roofing Tile Company, as follows:

TABLE LXII. SHRINKAGE UPON SIMPLE DRYING OF SPRINGWELLS CLAY.

Percentage of water loss.	Percentage of shrinkage.
2.0%	1.0%
4.0	4.5
12.3	5.0
17.0	5.0

This table indicates that although the loss of water beyond 12.3% continues, the shrinkage ceases at 5%. The fire shrinkage is indicated in the following table:

TABLE LXIII. SHRINKAGE UPON FIRING OF SPRINGWELLS CLAY.

Cone	.010	.08	.06	.04	.02	1	2	3	4	5
% Shrinkage ..	0	0	0	.50	.50	2.50	3.75	5.50	6.00	Melting.

These experiments were conducted in a small kiln, "under commercial conditions," and indicate a fusing point of approximately 2246° F. (1230°C.) for the clay. With long continued firing, as in the actual kiln, Mr. Worcester thinks that the clay would fuse at about cone 3, or 2174°F. (1190°C.). The following table shows the composition of ordinary brick clays, giving the range met with and the average percentage of each ingredient.

TABLE LXIV. CHEMICAL COMPOSITION OF COMMON BRICK CLAYS. (RIES.)

Constituent.	Range.	Average.
Silica (SiO_2)	34.350-90.877%	49.270%
Alumina (Al_2O_3)	22.140-44.000	22.774
Ferric oxide (Fe_2O_3)	0.126-33.120	5.311
Calcium oxide (CaO)	0.024-15.380	1.513
Magnesium oxide (MgO)	0.020- 7.290	1.052
Alkalies (K_2O, Na_2O, NH_3)	0.170-15.320	2.768
Water (H_2O) chemically combined...	0.050-13.600	5.749
Moisture mechanically combined	0.170- 9.640	2.502

These lake clays are utilized mainly in the manufacture of the common variety of building brick, some two dozen plants being so employed, one of them making also drain tile. In general, only the "soft mud" process is employed, the brick being moulded

by hand or machinery and ordinarily "burned" in the familiar type of "scove kiln." These kilns are loosely constructed each time of thoroughly dried brick to be burned, are of rough, rectangular form, crossed at the base with a series of parallel arches in which the fuel is consumed and the heat generated. The top of the mass is covered with a more tightly fitting layer of brick ("platting") while the sides and ends are daubed with mud to exclude the cold air while the burning takes place. Wood, coal and coke have been used as fuel but are now almost entirely replaced by crude oil. The burning requires from 5 to 7 days, depending upon the nature and condition of the clay and the atmospheric conditions prevailing at the time. At a few of the yards, especially where the drying is done artificially in steam-heated rooms, the burning is done in kilns more permanently constructed and provided with the "down-draft" system, thus securing a more uniform distribution of the heat. At the Clippert plant dryers are used with a capacity of 64,000 brick into which they are introduced at a temperature of 160°F. and pushed along to where the temperature is about 212°F. The air is heated by the fan system, drawn in over hot coils and about 48 hours are required for the drying. Many millions of brick have been burned here for years, the shallower deposits of clay nearer the city being gradually used up and the works shifted westward along Michigan Avenue. The markets have been mainly local, the product delivered by teams, but some have also been shipped by rail to various parts of southern Michigan and northern Ohio. Most of the yards are operated 5½ to 6 months of the year, closing down with the advent of freezing weather in the fall. Two or three of the larger plants, however, are so equipped that they can operate the year round, the clay being handled with steam shovels and small cable-drawn carts.

The manufacture of pressed brick was attempted for a short time by the Detroit Red Pressed Brick Co. but soon given up, the clay not being well adapted to this style of brick. According to the observations and experiments of Mr. W. G. Worcester, the clay has a strong tendency to laminate, thus unfitting it for pressed brick, as well as those made by stiff-mud processes. These clays were found to possess very high cross breaking strength while in dry condition, permitting their use for thin section ware. A small plant is in operation at Fifty-Ninth St., just south of Michigan Avenue, for the manufacture of flower-pots.

Drain tile are manufactured at the plant of J. C. McDonald and Son, Warren Ave. (SW. ¼ sec. 4, Springwells), in addition to the common brick. The local markets only are supplied, this being

the only tile plant within the limits of the county at present. The southern part of the county, however, is supplied with drain tile from the John Strong plant at South Rockwood, just south of the Huron. The chief demand is for 3 and 4-in. sizes but 2½, 6 and a few 8-inch sizes are also manufactured. Only the circular style is made, which burn to a pale red in down-draft kilns in about 3½ to 5 days. The "stiff mud" process is employed in moulding the tile and about a week's time is required for drying. The Detroit Roofing Tile Co., one of but 13 now in this country, has been in operation since 1905, located alongside the Michigan Central Ry., halfway between West End and Woodmere. Here they have 12 feet of clay well suited to their purpose, overlain by 3 feet of sandy loam stripping. After being thoroughly worked in the pug mill, the raw clay is allowed to "age" for 3 to 4 days by which process it is considerably toughened. The soft mud process is employed and many styles and varieties of interlocking roofing tile are turned out, most of which are shipped to the Atlantic coast and south as far as New Orleans. The local demand for this product is growing and seems destined to greatly increase because of its durability and artistic qualities.

Some 40 to 50 years ago, the city of Detroit was supplied with brick mainly from the vicinity of Leesville, Gratiot Ave., where some 6 feet of a yellow clay were available. The plants were located from a half mile south to a mile north of the village and some were in operation as late as 1900. Although the clay suitable for brick was not entirely exhausted, the business has been shifted to Michigan Avenue. Brick are also manufactured at Dearborn, in the southeastern part of the village, by Anthony Wagner and shipped to neighboring cities. The clay is of a brownish yellow variety, about 7 feet deep and said to extend over about 28 acres, about one-half of which has been used. It burns to a good shade of red in about 8 days, the plant running from 6 to 7 months each year. Both brick and tile were manufactured in the SE. ¼ NE. ¼ sec. 26, Redford township, up to about 1892, supplying the local demand only. There is said to occur here some 40 acres of suitable clay, from 6 to 10 feet thick. Brick and tile have been manufactured for many years by Milton E. Carlton, SE. ¼ NE. ¼ sec. 28, Canton township, the clay being obtained from the Rouge flats, brown in color and about 4 feet thick. Below this clay is a sandy type of clay, utilizable for brick but not tile. Two down-draft kilns are used for burning the product. Brick were made some 35 to 40 years ago at the NW. ¼ NW. ¼ sec. 5, Dearborn, to

supply the demand for use in chimneys when the old fashioned stick and mud chimneys passed out of date. Some drain tile were also made here, only surface clays being available. For a time, some brick were also burned in sec. 33 of Redford (NE. 1/4 NE. 1/4). Farther north in sec. 10 (SW. 1/4 NW. 1/4), S. K. Burgess began making brick and a few tile in 1871,—at the time of visit, the plant being operated by L. J. Burns. The clay is stratified, 4 to 5 feet thick and overlain by 4 to 8 inches of surface soil, containing enough sand so that none needs to be added. Below the clay is two feet of quick sand and then blue clay ("till"). The stiff clay process was the one employed. In the village of Northville, along the Rouge (NE. 1/4 NE. 1/4 sec. 9), a small brick establishment was operated for a time by Walter Randall, the bricks made being perforated at either end with a 5/8-inch hole (stiff clay process). The clay deposit was 4 to 5 feet thick and contained some pebbles; burning very unsatisfactorily, to a yellow, then red and sometimes a dark purple.

That the clays of Wayne County have not been utilized in the manufacture of Portland cement is due probably to the absence of any very extensive beds of marl, or "bog lime." An entirely suitable rock can be obtained from the Sibley and Macon quarries, but is in great demand for the purification of beet sugar and the manufacture of soda-ash.

Sand, gravel and boulders. Along the broad belts described and mapped as the Wayne, Grassmere and Elkton beaches, almost unlimited quantities of a more or less pure yellow sand are available. Although heaped up by wind action, and with little sign of stratification, a small percentage of clay is generally present. Many such ridges and mounds are entirely free from pebbles. The most accessible deposits are those near Sand Hill and Romulus, but less extensive ones can be reached along any of the steam and electric roads leading out from Detroit. The Maumee, Whittlesey and Warren beaches contain poorly assorted patches of a sharper, gray sand, interstratified with gravel strata. The kame hills in the northwestern corner of the county, although largely gravel, contain also some sand which locally became separated from the pebbles. The gravel in the kames is generally pretty well assorted but differs considerably in different ones, as might be expected. The pebbles are rounded to subangular and consist of 40 to 50% of limestone and dolomite, with 12 to 20% each of chert, quartzite and igneous fragments. The sandstone and argillites were largely eliminated from the deposits, perhaps by stream action. In the case of one

kame from which 200 pebbles were collected at random (NW. 1/4 SE. 1/4 sec. 11, Northville) and then classified, the limestones and dolomites numbered but 9 (4 1/2%), with a corresponding increase in the number of the harder fragments. If the sample studied fairly represents the entire kame such gravel would have much higher value for road construction; since the limestones and dolomites are more readily ground to powder and blown away. The composition of the beach pebbles does not differ greatly from those of the kames, being slightly lower in the limestones and dolomites and somewhat higher in the quartzites and igneous varieties. The location of these beaches, especially rich in gravel, as the younger ones are in sand, is shown upon Pl. X. Nearly the entire upper two-thirds of Northville township is dotted with gravel deposits; especially sections 2 to 11, inclusive. Many of these could be made very accessible by building short spurs from the Pere Marquette Ry. and the electric lines. Much of this gravel has been already utilized in road building in Northville and Plymouth townships, but comparatively little has been shipped outside.

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When run through heavy crushers, both the limestone and dolomite are converted into road metal, for macadamizing purposes, for which there has been considerable demand. Much of this has also been used in providing a dustless and weedless ballast for the steam and electric railways. The demand for such material seems to have slackened, since the Patrick and Gibraltar quarries have been temporaily abandoned and the two great dump heaps of the Livingstone cut (Pl. V, A) are to remain unutilized. The Sibley quarry converts its rock, unsuited to other purposes, into macadam (Pl. XXXI, A).

When subjected to heat, the high grade limestone of the Sibley quarry loses its carbon dioxide gas and is converted into calcium oxide, or quick-lime ($CaCO_3 - CO_2 = CaO$). This has the well known property of uniting with water ("slaking"), forming calcium hydrate, with the evolution of much heat ($CaO + H_2O = Ca(OH)_2$). In this form, it is sparingly soluble in water, forming "limewater," useful as a mild form of alkali in medicines and various industries. When a slush of calcium hydrate is mixed with sand, to prevent shrinkage and to render it more porous, and exposed to the air, the carbon dioxide of the atmosphere unites with the hydrate forming lime carbonate over again and water ($Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$). The excess of water originally present, as well as that newly formed, is evaporated and the mortar, or plaster, is slowly hardened, adapting it to the familiar building uses. An excellent quality of lime is made at the Sibley quarry in iron kilns of the "continuous" type, which are fed periodically with suitable stone at the top and from which there is periodically removed the fresh lime at the bottom. These are a great improvement over the side-hill stone kilns in vogue a few years past. The dolomites yield a different type of lime, which slakes more slowly, develops less heat, capable of binding less sand and requiring more time for setting. The chemical action taking place is shown by the following equation, showing that magnesium oxide ($CaO.\ MgO + H_2O = Ca(OH)_2.\ MgO$) is combined with the calcium hydrate. When once thoroughly set, however, the product is often harder than that obtained from the limestones, partaking sometimes of the character of hydraulic cement. Owing to their in-

accessibility, these dolomitic strata were not much used in Wayne County in an early day, the supply of this type of lime coming from Monroe County. Some 25 years ago, small quantities of lime were burned at Flat Rock by James and William Breeland, father and son, the rock being obtained from the bed of the Huron.

The impression has been held by different individuals that the Monroe dolomites, upon being properly handled, should yield hydraulic cement which differs from ordinary plaster and mortar in that it will harden out of contact with air, as under water, thus adapting it to many new uses. The rock employed which may be either a limestone or dolomite, should contain some 15 to 35% of clay and a little potash or soda. The presence of sand in the form of grit is objectionable. The analyses of the Monroe County strata and the few experiments that have been made upon them have not held out much prospect of success along this line.[2] An artificial mixture of calcium carbonate (72 to 77%) with a silicious, but not gritty clay (23 to 28%), containing potash or soda, may be heated to a high temperature (2900°F.) and reduced to powder, forming Portland cement. During the so-called "burning" there are formed tricalcium ortho-silicate ($3CaO, SiO_2$) and tricalcium aluminate ($3CaO, Al_2O_3$),[3] which, upon becoming wet, are converted into crystalline insoluble hydrates of calcium and aluminum. Certain beds of the Sibley quarry could be selected, which with the lake clays of the West Detroit area would give the right combination for the manufacture of this much utilized product.

Sand-lime brick. Wayne County possesses two plants for the manufacture of this type of building material, in which Michigan leads all other states. The industry is but 12 years old in this country, having been introduced from Germany, and consists in the moulding of brick from a mixture of lime (CaO) and quartz sand (SiO_2). As carried out by the Sibley Brick Company, operating since 1904, thoroughly hydrated lime of their own manufacture is ground to powder and mixed with sand, sucked from the bed of Lake Erie, near Gibraltar. Any type of silicious sand may be used which is reasonably free from clay and not too coarse, but those sands are preferred in which there is considerable variation in the size of grain. The granules should be sharp and angular to secure the best results, so that the Sylvania with its rounded, evenly assorted granules is not ideally adapted to this use. The lime used should be as free as possible from any content of mag-

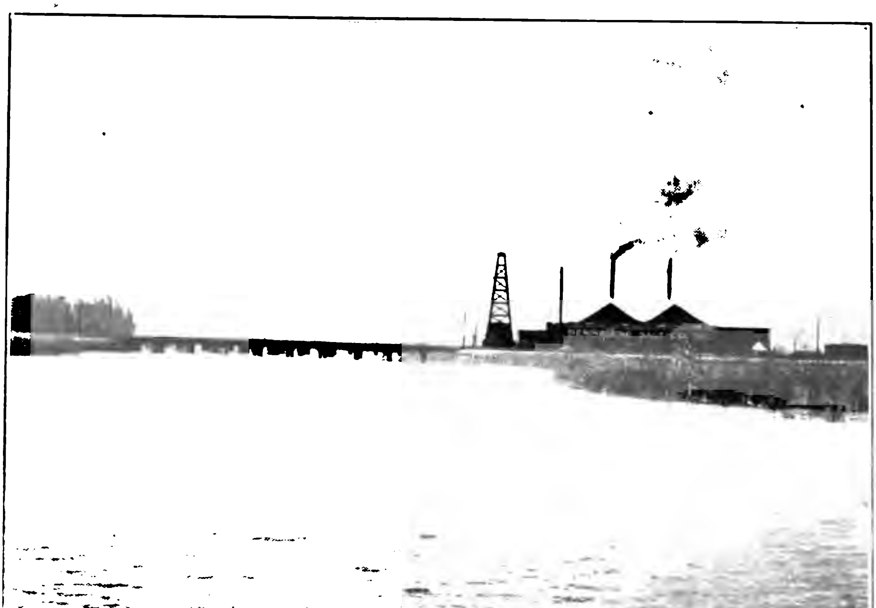
2. See Geological Report on Monroe County, 1900, p. 180. Geological Survey of Michigan, vol. VII, pt. 1.
3. Along with tricalcium aluminoferrite, $3CaO2(AlFe)_2O_3$.

nesia. Five shovels-full of moist sand are thoroughly mixed with one of the powdered lime hydrate, producing a mixture in which about 95% is silica and 5% lime. The bricks are moulded under a pressure of 8,000 lbs. to the square inch, placed in a boiler and subjected to a steam pressure of 125 lbs. to the square inch for 10 hours, giving rise to a chemical union of the calcium and silica to form calcium silicate ($CaSiO_3$). The bricks are then allowed to stand for about three months before being placed upon the market, during which an absorption of carbon dioxide gas from the atmosphere occurs. The bricks thus produced are a very light gray, perfectly formed, with sharp edges and smooth surfaces and have undergone practically no shrinkage or warping. They may be colored to almost any desired shade. Subjected to pressure tests it has been found that they show greater regularity than common brick and a crushing strength equal to that demanded for brick of good quality. The average of 255 tests gave an average of 2190 lbs. pressure per square inch. The loss of strength through the absorption of water averaged 14%. The amount of water absorbed amounted to 14.9% weight and 26.3% volume, less than for ordinary clay brick, while the test with heat and sudden dash of water shows that they stand up as well as the clay. Mortar is found to adhere slightly better to the sand-lime brick than to those made of clay and because of their more nearly uniform size and shape they can be more rapidly laid. In localities where clay is absent or scarce and sand and lime abundant, this type of brick is bound to come into favor. In addition to the plant at Sibleys, they are also manufactured in Detroit by the Michigan Pressed Brick Co., corner of Lawton Avenue and the Michigan Central Railway, this present company having operated since 1908. The lime is obtained from the Sibley Quarry Co. and the sand from near Rochester, Michigan.

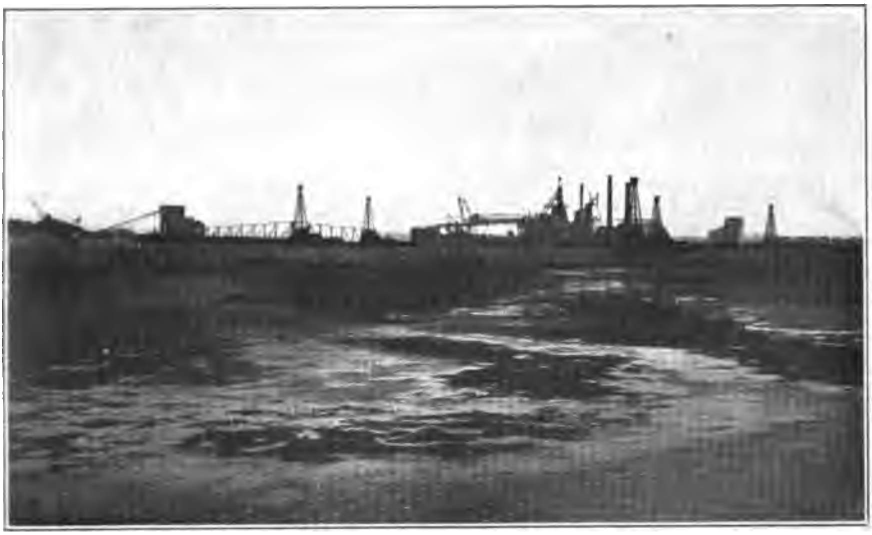
CHEMICAL MATERIALS FOR DIRECT USE OR MANUFACTURE.

Calcium carbonate. High grade calcium carbonate with very little or no magnesia, and small percentages of silica and iron, is in great demand for the manufacture of soda-ash (Na_2CO_3) and the purification of beet sugar, in both of which industries Michigan holds a leading rank. The rock should contain from 95 to 99% of the calcium carbonate and can be obtained from the "9-foot bed" of the Sibley quarry, which averages 98% pure. The Anderdon bed has been reached in the deeper excavations of the quarry and will probably be found to carry a uniformly high percentage

A. NEAR VIEW OF SIBLEY CRUSHING PLANT.



B. PLANT OF PENINSULA SALT COMPANY AND RIVER ROUGE.



A. PLANT OF SOLVAY PROCESS COMPANY, DELRAY, FOR THE MANUFACTURE OF SODA ASH.

B. SURFACE PLANT OF OAKWOOD SALT SHAFT, MICHIGAN'S ONLY SALT MINE.

relative to the air and fire shrinkage have been obtained by W. G. Worcester, formerly superintendent of the Detroit Roofing Tile Company, as follows:

TABLE LXII. SHRINKAGE UPON SIMPLE DRYING OF SPRINGWELLS CLAY.

Percentage of water loss.	Percentage of shrinkage.
2.0%	1.0%
4.0	4.5
12.3	5.0
17.0	5.0

This table indicates that although the loss of water beyond 12.3% continues, the shrinkage ceases at 5%. The fire shrinkage is indicated in the following table:

TABLE LXIII. SHRINKAGE UPON FIRING OF SPRINGWELLS CLAY.

Cone	.010	.08	.06	.04	.02	1	2	3	4	5
% Shrinkage ..	0	0	0	.50	.50	2.50	3.75	5.50	6.00	Melting.

These experiments were conducted in a small kiln, "under commercial conditions," and indicate a fusing point of approximately 2246° F. (1230°C.) for the clay. With long continued firing, as in the actual kiln, Mr. Worcester thinks that the clay would fuse at about cone 3, or 2174°F. (1190°C.). The following table shows the composition of ordinary brick clays, giving the range met with and the average percentage of each ingredient.

TABLE LXIV. CHEMICAL COMPOSITION OF COMMON BRICK CLAYS. (RIES.)

Constituent.	Range.	Average.
Silica (SiO_2)	34.350-90.877%	49.270%
Alumina (Al_2O_3)	22.140-44.000	22.774
Ferric oxide (Fe_2O_3)	0.126-33.120	5.311
Calcium oxide (CaO)	0.024-15.380	1.513
Magnesium oxide (MgO)	0.020- 7.290	1.052
Alkalies (K_2O, Na_2O, NH_3)	0.170-15.320	2.768
Water (H_2O) chemically combined...	0.050-13.600	5.749
Moisture mechanically combined	0.170- 9.640	2.502

These lake clays are utilized mainly in the manufacture of the common variety of building brick, some two dozen plants being so employed, one of them making also drain tile. In general, only the "soft mud" process is employed, the brick being moulded

by hand or machinery and ordinarily "burned" in the familiar type of "scove kiln." These kilns are loosely constructed each time of thoroughly dried brick to be burned, are of rough, rectangular form, crossed at the base with a series of parallel arches in which the fuel is consumed and the heat generated. The top of the mass is covered with a more tightly fitting layer of brick ("platting") while the sides and ends are daubed with mud to exclude the cold air while the burning takes place. Wood, coal and coke have been used as fuel but are now almost entirely replaced by crude oil. The burning requires from 5 to 7 days, depending upon the nature and condition of the clay and the atmospheric conditions prevailing at the time. At a few of the yards, especially where the drying is done artificially in steam-heated rooms, the burning is done in kilns more permanently constructed and provided with the "down-draft" system, thus securing a more uniform distribution of the heat. At the Clippert plant dryers are used with a capacity of 64,000 brick into which they are introduced at a temperature of 160°F. and pushed along to where the temperature is about 212°F. The air is heated by the fan system, drawn in over hot coils and about 48 hours are required for the drying. Many millions of brick have been burned here for years, the shallower deposits of clay nearer the city being gradually used up and the works shifted westward along Michigan Avenue. The markets have been mainly local, the product delivered by teams, but some have also been shipped by rail to various parts of southern Michigan and northern Ohio. Most of the yards are operated 5½ to 6 months of the year, closing down with the advent of freezing weather in the fall. Two or three of the larger plants, however, are so equipped that they can operate the year round, the clay being handled with steam shovels and small cable-drawn carts.

The manufacture of pressed brick was attempted for a short time by the Detroit Red Pressed Brick Co. but soon given up, the clay not being well adapted to this style of brick. According to the observations and experiments of Mr. W. G. Worcester, the clay has a strong tendency to laminate, thus unfitting it for pressed brick, as well as those made by stiff-mud processes. These clays were found to possess very high cross breaking strength while in dry condition, permitting their use for thin section ware. A small plant is in operation at Fifty-Ninth St., just south of Michigan Avenue, for the manufacture of flower-pots.

Drain tile are manufactured at the plant of J. C. McDonald and Son, Warren Ave. (SW. ¼ sec. 4, Springwells), in addition to the common brick. The local markets only are supplied, this being

the only tile plant within the limits of the county at present. The southern part of the county, however, is supplied with drain tile from the John Strong plant at South Rockwood, just south of the Huron. The chief demand is for 3 and 4-in. sizes but 2½, 6 and a few 8-inch sizes are also manufactured. Only the circular style is made, which burn to a pale red in down-draft kilns in about 3½ to 5 days. The "stiff mud" process is employed in moulding the tile and about a week's time is required for drying. The Detroit Roofing Tile Co., one of but 13 now in this country, has been in operation since 1905, located alongside the Michigan Central Ry., halfway between West End and Woodmere. Here they have 12 feet of clay well suited to their purpose, overlain by 3 feet of sandy loam stripping. After being thoroughly worked in the pug mill, the raw clay is allowed to "age" for 3 to 4 days by which process it is considerably toughened. The soft mud process is employed and many styles and varieties of interlocking roofing tile are turned out, most of which are shipped to the Atlantic coast and south as far as New Orleans. The local demand for this product is growing and seems destined to greatly increase because of its durability and artistic qualities.

Some 40 to 50 years ago, the city of Detroit was supplied with brick mainly from the vicinity of Leesville, Gratiot Ave., where some 6 feet of a yellow clay were available. The plants were located from a half mile south to a mile north of the village and some were in operation as late as 1900. Although the clay suitable for brick was not entirely exhausted, the business has been shifted to Michigan Avenue. Brick are also manufactured at Dearborn, in the southeastern part of the village, by Anthony Wagner and shipped to neighboring cities. The clay is of a brownish yellow variety, about 7 feet deep and said to extend over about 28 acres, about one-half of which has been used. It burns to a good shade of red in about 8 days, the plant running from 6 to 7 months each year. Both brick and tile were manufactured in the SE. ¼ NE. ¼ sec. 26, Redford township, up to about 1892, supplying the local demand only. There is said to occur here some 40 acres of suitable clay, from 6 to 10 feet thick. Brick and tile have been manufactured for many years by Milton E. Carlton, SE. ¼ NE. ¼ sec. 28, Canton township, the clay being obtained from the Rouge flats, brown in color and about 4 feet thick. Below this clay is a sandy type of clay, utilizable for brick but not tile. Two down-draft kilns are used for burning the product. Brick were made some 35 to 40 years ago at the NW. ¼ NW. ¼ sec. 5, Dearborn, to

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When subjected to heat, the high grade limestone of the Sibley quarry loses its carbon dioxide gas and is converted into calcium oxide, or quick-lime ($CaCO_3—CO_2=CaO$). This has the well known property of uniting with water ("slaking"), forming calcium hydrate, with the evolution of much heat ($CaO+H_2O=Ca(OH)_2$). In this form, it is sparingly soluble in water, forming "limewater," useful as a mild form of alkali in medicines and various industries. When a slush of calcium hydrate is mixed with sand, to prevent shrinkage and to render it more porous, and exposed to the air, the carbon dioxide of the atmosphere unites with the hydrate forming lime carbonate over again and water ($Ca(OH)_2+CO_2=CaCO_3+H_2O$). The excess of water originally present, as well as that newly formed, is evaporated and the mortar, or plaster, is slowly hardened, adapting it to the familiar building uses. An excellent quality of lime is made at the Sibley quarry in iron kilns of the "continuous" type, which are fed periodically with suitable stone at the top and from which there is periodically removed the fresh lime at the bottom. These are a great improvement over the side-hill stone kilns in vogue a few years past. The dolomites yield a different type of lime, which slakes more slowly, develops less heat, capable of binding less sand and requiring more time for setting. The chemical action taking place is shown by the following equation, showing that magnesium oxide ($CaO.\ MgO+H_2O=Ca(OH)_2.\ MgO$) is combined with the calcium hydrate. When once thoroughly set, however, the product is often harder than that obtained from the limestones, partaking sometimes of the character of hydraulic cement. Owing to their in-

accessibility, these dolomitic strata were not much used in Wayne County in an early day, the supply of this type of lime coming from Monroe County. Some 25 years ago, small quantities of lime were burned at Flat Rock by James and William Breeland, father and son, the rock being obtained from the bed of the Huron.

The impression has been held by different individuals that the Monroe dolomites, upon being properly handled, should yield hydraulic cement which differs from ordinary plaster and mortar in that it will harden out of contact with air, as under water, thus adapting it to many new uses. The rock employed which may be either a limestone or dolomite, should contain some 15 to 35% of clay and a little potash or soda. The presence of sand in the form of grit is objectionable. The analyses of the Monroe County strata and the few experiments that have been made upon them have not held out much prospect of success along this line.[2] An artificial mixture of calcium carbonate (72 to 77%) with a silicious, but not gritty clay (23 to 28%), containing potash or soda, may be heated to a high temperature (2900°F.) and reduced to powder, forming Portland cement. During the so-called "burning" there are formed tricalcium ortho-silicate ($3CaO, SiO_2$) and tricalcium aluminate ($3CaO, Al_2O_3$).[3] which, upon becoming wet, are converted into crystalline insoluble hydrates of calcium and aluminum. Certain beds of the Sibley quarry could be selected, which with the lake clays of the West Detroit area would give the right combination for the manufacture of this much utilized product.

Sand-lime brick. Wayne County possesses two plants for the manufacture of this type of building material, in which Michigan leads all other states. The industry is but 12 years old in this country, having been introduced from Germany, and consists in the moulding of brick from a mixture of lime (CaO) and quartz sand (SiO_2). As carried out by the Sibley Brick Company, operating since 1904, thoroughly hydrated lime of their own manufacture is ground to powder and mixed with sand, sucked from the bed of Lake Erie, near Gibraltar. Any type of silicious sand may be used which is reasonably free from clay and not too coarse, but those sands are preferred in which there is considerable variation in the size of grain. The granules should be sharp and angular to secure the best results, so that the Sylvania with its rounded, evenly assorted granules is not ideally adapted to this use. The lime used should be as free as possible from any content of mag-

2. See Geological Report on Monroe County, 1900, p. 180. Geological Survey of Michigan, vol. VII, pt. 1.
3. Along with tricalcium aluminoferrite, $3CaO2(AlFe)_2O_3$.

of this carbonate, as at the Anderdon quarry upon the eastern side of Detroit River. One of the first steps in the manufacture of the so-called soda-ash is to secure a quantity of ammonium hydrogen carbonate (NH_4HCO_3) and this is done by saturating water with ammonia gas and passing through it a current of carbon dioxide gas, obtained by heating calcium carbonate as in the manufacture of quick lime previously described. The reaction that takes place is indicated by the following equation:

$$(1)\quad NH_3+H_2O+CO_2=NH_4HCO_3.$$

This product is converted into sodium carbonate, through the agency of salt in a way to be mentioned later.

In the manufacture of beet sugar, a high grade limestone is also required, a plant using 300 tons of beets daily needing from 35 to 40 tons of limerock. Both the quick lime and carbon dioxide gas obtained by heating the calcium carbonate are utilized, the two being again united. Too much silica, silicates and alumina cause trouble in the burning, while magnesia and gypsum interfere with the filtering and evaporation of the juice. The lime in the form of powder, or in solution as "milk of lime," is added to the beet juice and unites mechanically and chemically with the impurities present. The addition then of the carbon dioxide gas brings about a union between it and the calcium hydrate, according to the equation previously given:

$$Ca(OH)_2+CO_2=CaCO_3+H_2O.$$

The calcium carbonate appears as a flaky precipitate and settles to the bottom carrying its load of impurities, being then readily separated from the juice by filtering. At present this material is carted away as waste and used as a land fertilizer by the farmers. If some practical scheme for purifying it could be devised the calcium carbonate could be recovered, with some necessary waste, and utilized over and over again. The exhaustion of the supply of suitable limestone may eventually make this necessary. Lime is still further used in recovering from the "molasses" its final content of sugar, forming with it tricalcium saccharate, $C_{12}H_{19}O_{11}.(CaOH)_3$. From this saccharate, both the sugar and the calcium hydrate may be recovered. Were it not for the heavy covering of drift the section of country between Sibley and Dundee would supply a high grade carbonate for many years to come.

Deposits of marl occur only in limited amounts in the county and usually in too impure condition to be used for the production of soda-ash or beet sugar, but entirely suitable for cement manufacture, for quicklime and as a fertilizer. This form of calcium carbonate is produced in ponds and swamps through the action of

plant and animal organisms in secreting from the water the calcium carbonate there held in solution. The mollusca extract this substance for use in the production of their shells and, upon their death, the animal substances decay and these shells may accumulate in quantity, before undergoing complete solution again. The amount of calcium carbonate (actually in the form of the bicarbonate $CaH_2(CO_3)_2$ held in solution is dependent upon the presence of the carbon dioxide gas in the water, and when this gas is abstracted by green plants, for their use in securing carbon, the calcium carbonate is deposited often over their stems and leaves in the form of minute crystals forming an incrustation. One very common plant of this character forms thick mats over the bottoms of our ponds and is known as *Chara*. It secretes and deposits so much of the calcium carbonate as to render its slender leaves and branches quite brittle, suggesting that this material may be deposited as the result of some physiological action on the part of the plant. Upon the decay of these and related plants quantities of the slightly soluble calcium carbonate collect upon the bottom and give rise to a chalky deposit known as marl. It is evident that shells may also be present in greater or less quantity and more or less mineral impurity in the form of sand and clay.[4] Under favorable conditions deposits many feet in thickness have been formed since the withdrawal of the ice sheet from Michigan. In Wayne County, however, owing to its long submergence by the glacial lakes and the almost complete absence of subsequent ponds and minor lakes no very extensive deposits were formed. Although favorable conditions for marl formation and deposition occur about the present margins of Lake St. Clair, Detroit River and Lake Erie, the time that these present conditions have existed seems of too short duration. In the vicinity of the swamps, those still existent and those which have been drained, often in association with peat, shallow deposits of marl are found; as in secs. 5, 8, NE. ¼ sec. 28, of Brownstown; secs. 9, 10, 15 and 16 of Sumpter; NE. ¼ sec. 18 of Canton. This latter deposit is estimated to cover some 10 acres, to be 2 to 3 feet thick and is overlain by 10 to 16 inches of muck. These marl beds could all be utilized as a land fertilizer and when mixed with thoroughly dried and disintegrated peat would add very greatly to the fertility of the soil.

Glass sand. The Sylvania sandrock formation, described as of probable æolian origin, has all the qualities needed for high grade glass manufacture. It is finely and uniformly grained, runs very

4. For a discussion of the origin of marl, its occurrence and uses see report in the Geological Survey of Michigan, vol. VIII, pt. III, 1903.

high in silica and is so incoherent that it is readily disintegrated by water and pumped from the pit. Mixed with the fusible bases it melts readily and yields a glass free from color. This sand has been mined and marketed for a number of years in Monroe County, where there was a natural outcrop. The bed strikes northeastward, with an outcrop of two to three miles beneath the drift cover, and crosses the southern point of Brownstown township, as shown upon Pl. XXV. Just east of Rockwood, upon the land of Dr. Dayton Parker (NW. ¼ SE. ¼ sec. 15) a pit has been opened under 15 to 18 feet of a hard glacial till and is operated by the American Silica Co. The deposit here is said to be 75 feet thick, but all of this will probably not yield to the hydraulic treatment now employed. A sample of this washed sand was analyzed by Dr. John E. Clark, Detroit, and gave 99.70% silica (SiO_2); .08% calcium carbonate ($CaCO_3$); .22% magnesium carbonate ($Mg\ CO_3$). The Rockwood Silica Sand Co. acquired 82 acres of land just east of the Grand Trunk Ry. (SE.¼ SW.¼ sec.10), and three years ago sunk a well to the depth of 122 feet, through 15 feet of clay. An additional 15 feet of limestone (dolomite) was penetrated when the glass sand was entered to a depth of 92 feet, without reaching the base. A 6-inch casing was used to the rock and below a 4-inch, through which steam under 60 lbs. pressure is forced, bringing out water and sand. The sand is dried and screened to the amount of about a carload a day, being shipped to Ohio and Pennsylvania. The water from the well contains sulphur and when allowed to do so rises to within 3 feet of the surface. In the Oakwood salt shaft, the bed was reached at a depth of 420 feet, has a thickness of 113 feet and much of it could be removed if it was desired to do so, using the same hoisting machinery as that employed for the salt.

Mineral waters. Although all natural water may be regarded as a *mineral resource*, Chapter VII has been devoted to its discussion and there has been reserved for this section only a brief discussion of those waters which are economically valuable because of their mineral content. The waters which permeate the beds of the Dundee and Monroe formations become heavily charged with a great variety of minerals; chief of which are sulphur, salt, calcium and magnesium sulphate and carbonate. When heated and properly administered, such waters have undoubted medicinal value for certain diseases and are in demand. By penetrating the proper horizon, almost unlimited quantities may be obtained over the entire county. Two plants are in operation in Detroit,

Riverside Bath House, Clarke Ave. and Fort.

Detroit Mineral Bath Co., Cor. 21st St. and Fort.

The various industries utilizing the salt deposits along Detroit River (Pls. XXXI, B and XXXII, A) from Delray to Trenton, prepare an artificial brine by forcing the water of the river to the salt strata, where it becomes saturated and flows to the surface. The salt is then recovered by the evaporation of the water and marketed as such, or utilized in the manufacture of soda-ash and caustic soda. As explained in an earlier part of this chapter the first step in the manufacture of the former product (Na_2CO_3) is the production of ammonium hydrogen carbonate (NH_4HCO_3), by the use of ammonia and carbon dioxide. When this solution receives a strong solution of salt ($NaCl$), two new substances are formed: sodium hydrogen carbonate ($NaHCO_3$), or bicarbonate of soda, and ammonium chloride (NH_4Cl), as shown in the following equation:

$$(2) \quad NaCl+NH_4HCO_3=NaHCO_3+NH_4Cl.$$

The sodium hydrogen carbonate is but sparingly soluble and is precipitated and recovered. This is the common baking soda which is manufactured extensively at Ford City and formerly at Trenton. Upon being heated in a retort, this compound breaks up into its three components, according to the following equation:

$$(3) \quad 2NaHCO_3=Na_2CO_3+H_2O+CO_2.$$

Upon being treated with lime, the ammonium chloride of equation 2, is converted into calcium chloride ($CaCl_2$), with the liberation of ammonia and water.

$$(4) \quad 2NH_4Cl+CaO=CaCl_2+2NH_3+H_2O.$$

It is thus seen from equations 3 and 4 that all of the ammonia and half of the carbon dioxide gas are recovered and may be used in the further production of ammonium hydrogen carbonate, according to equation 1. The calcium chloride containing the calcium of the lime and the chlorine of the salt, form the by-product, great quantities of which may be seen about the plants of the soda-ash manufacturies at Delray and Wyandotte. When heated, this becomes a valuable drying agent because of its strong attraction for water. The soda-ash sought contains the sodium of the salt and the carbonate radical (CO_3) of the limestone, which has been exchanged for the chlorine. This is known in the market as *sal soda*, is used extensively for softening water, in the manufacture of glass and numerous other chemicals. When dissolved and treated with calcium hydrate ($Ca(OH)_2$), a recombination occurs.

$$(5) \quad Na_2CO_3+Ca(OH)_2=CaCO_3+2NaOH,$$

resulting in the formation of lime carbonate and sodium hydroxide, commonly known as *caustic soda*, or "alkali." This is extensively

SECTION OF OAKWOOD SALT SHAFT.

System	Formation	Thickness	Section	Depth	Elevation	Character of Rock
					575 A.T.	
Pleistocene Wis.	Drift	83		83	492	Blue boulder clay, glacial origin. 10 foot sand deposit.
Devonian Middle	Dundee	63		146	429	High grade limestone with some chert nodules.
Silurian Upper Monroe	Lucas	170		316	259	Bluish to brownish-gray dolomite, much of it finely laminated, with streaks of asphaltum. Small amount of gypsum. Poor in fossils.
Silurian Upper Monroe	Amherstburg	19		335	240	Brownish laminated dolomite.
Silurian Upper Monroe	Anderson	38		373	202	High grade limestone, rich in fossils. Some celestite.
Silurian Upper Monroe	Flat Rock	47		420	155	Dark drab dolomite, with few casts and moulds of fossils. Some concretions and gypsum.
Silurian Middle Monroe	Sylvania	113		533	42	Snow white sandstone, more or less cross bedded. Generally incoherent, compacted into sandstone from about 490 to 510 feet.
Silurian Lower Monroe	Raisin River	124		657	-82	Bluish gray or brownish laminated dolomite, occasional oolitic strata, line of seperation between it and Sylvania very distinct. Some chert nodules and pyrite. Bed of breccia encountered about 580 feet. Some fossils.
Silurian Lower Monroe	Put in Bay Possibly including Tymochtee	220		877	-302	Bluish to brownish dolomite with seams of fossils. Thin strata of breccia and oolite. Some selenite, alabaster, anhydrite, calcite, asphaltum, and pyrite. Shaly and carbonaceous in places. Dolomite shows gashed structure at certain levels. Veins of salt encountered near bottom.
Silurian Division of upper series	Salina	83		960	-385	Salt and dolomite irregularly mixed. No fossils found.
		10		970	-395	Salt.
		50		1020	-445	Salt and dolomite.
		20		1040	-465	Salt slightly blotched with dol. slime.
						Present bottom of shaft.
		70		1110	-535	Salt and dolomite.
		30		1140	-565	Salt.
		199		1339	-764	Salt and dolomite.
		25		1364	-789	Salt.
		73		1437	-862	Dolomite.
		369		1806	-1231	Salt. When entered this will probably be found to be divided by minor strata of dolomite.

manufactured by the Michigan Alkali Co., at Ford City and used largely in the production of soap.

Rock salt. In a swamp bordering Detroit River, south of the River Ecorse, the first unsuccessful attempt was made in 1902 to sink a shaft for the mining of rock salt. The failure, however, was a success in that it presented the first serious problem, and suggested its solution. A square hole, 24 feet x 24 feet, was first dug to a depth of about 14 feet, passing through 4 feet of fresh muck, 2 feet of mucky clay and 4 to 6 feet of a mottled (yellow, brown and blue) lake, or river clay, carrying shells, but no pebbles. Then followed about 70 feet of soft, bluish-drab till, with some few pebbles, cobbles and boulders, the only break being at 30 feet where a 6 to 8-inch stratum of gravel, or gravelly clay, was encountered. A drop casing of brick, cylindrical in form, 15 feet in diameter and one foot thick was constructed and provided with a steel shoe. This was allowed to settle as the excavation proceeded and was added to at the top. At a depth of about 55 feet a great amount of "creep" was experienced, 48 hours' progress amounting to but 1½ feet, instead of about 14 feet. When within a short distance of the rock, at a depth of some 80 feet, the casing showed signs of weakening under the strain caused by the *creep* of the clay and, although an effort was made to strengthen it, the entire structure collapsed and the hole filled with water.

The second attempt to get at the solid salt has proven successful but only by the most determined effort and highest engineering skill. Reaching the solid rock, its removal proved comparatively simple, but the suffocating gases and floods of water encountered would have literally swamped and discouraged most companies. That the enterprise was brought to successful completion is due to the rare skill and judgment of the engineer in charge, Eugene F. Bradt and his corps of efficient helpers. The work was begun Dec. 12, 1904, by the "Detroit Salt Mining and Manufacturing Co.," capitalized at $500,000, and was intended to include later the Detroit Salt Co. and the River Rouge Salt Co. The site of the shaft is in Oakwood, a small Detroit suburb, just south of the Rouge about ½ mile and two miles from Detroit River. The elevation of the mouth of the shaft, as determined by W. C. Cooper, is 575.2 ft., above sea level. A drop shaft of timber was constructed, 6 ft. x 16 ft. in the clear (8 ft. x 18 ft. outside) with a cutting edge, protected by a sheet of steel. As the digging was carried on below the casing was allowed to settle and was built on above, passing through 73 feet of soft, blue clay (Wisconsin till) and 10 feet of sand and clay mixed, reaching bedrock (Dundee limestone) at

83 feet, or an actual elevation above sea level of 492 feet. This limestone was entered 17 feet, early in July, 1905, but was so strong in hydrogen sulphide gas (H_2S) that work was suspended until the 20th of November. The eyes of the men were painfully affected and some of the workmen were overcome. At one stage of the work, firemen's helmets were used, supplied with fresh air through rubber hose, but were found cumbersome and were then discarded. The almost imperceptible structural break between the Dundee and the Monroe came at about 146 feet and then followed the succession of strata making up the various divisions of the Monroe formation, as indicated in the section given on Fig. 21. Below 100 feet the casing was reduced to 5 ft. 4 in. x 15 ft. 4 in., inside measurements, the shaft being cased with 2 in. planking and 12 in. framing timbers.[5] The last week of June, 1909, the work extending over a period of 4½ years, an 8-foot stratum of salt was reached at a depth of 878 feet. With no water or gas now to cause trouble, it was simply a matter of time to reach the heavier deposits of purer salt, and, by the close of the year, a depth of 1042 feet had been reached, entering a 20-foot vein of salt which is the one now being worked by means of "drifts," (1040 to 1060 feet). The average monthly progress made was 17⅔ feet, the greatest record being made in the dolomite, April, 1909 (672 to 765 feet), amounting to 93 feet. This was accomplished by offering the men a bonus for all that was accomplished beyond a certain amount.

Six noteworthy water horizons were encountered as the work progressed as follows:

1. Depth 83 ft.; elevation 493 ft. Just over rock with a temperature of 52.2°F. (Cooper).

2. Depth 86 to 88 ft.; elevation 489 to 487 ft. Dundee limestone, quite heavy flow and rank in hydrogen sulphide gas.

3. Depth 135 ft.; elevation 440 ft. Dundee limestone, small flow.

4. Depth 155 to 168 ft.; elevation 420 to 407 ft. Lucas dolomite, porous. Flow continuing down to 181 ft., or elevation 394 ft. Sulphurous. Temperature at 180 ft. was 49.5° F. (Cooper).

5. Depth 191 ft.; elevation 384 ft. Remarkably heavy flow from a horizontal opening extending across the shaft. Lucas dolomite. Water strong in sulphur and under a pressure of 90 lbs. per square inch, causing the shaft to fill in 3 to 4 hours.

6. Depth 420 ft. to 533 ft.; elevation 155 ft. to 42 ft. above sea level. Seepage flow of sulphur water throughout Sylvania sand-

5. A detailed description of the shaft from an engineering standpoint will be found in the Engineering and Mining Journal, March 18, 1911, p. 565. "Shaft of the Detroit Salt Company" by Albert H. Fay.

stone, except for a 27-foot stratum of dry, silicious dolomite (Sylvania dolomite).

Mr. Bradt estimated the total flow above the base of the Sylvania as 2,000,000 gallons a minute, this being reduced to not over 500 gallons by the use of Portland cement forced into the fissures of the rock under a pressure of 1200 lbs. to the square inch. The vein at the depth of 191 feet required several carloads of cement before the flow could be controlled, and the services of a diver to insert the pipe at the proper point. Preparatory to blasting, holes were drilled obliquely about the margin of the shaft, one foot apart, and into these were forced all the cement slush that they would receive. In the case of the Sylvania, a concrete lining, 24 to 30 inches thick was required to restrain the flow. Below the Sylvania, the flow was greatly reduced and finally completely disappeared. The shaft was ventilated during the progress of the work by a canvas flue, in 50-foot lengths, and $4\frac{1}{2}$ feet in diameter, through which air was forced to the workmen.

The shaft is to be divided into three compartments, separated by board linings, two for the operation of the $2\frac{1}{2}$-ton skips and the third provided with a set of ladders for emergency purposes. A series of 10-inch holes is being drilled alongside the shaft to receive the steam and water pipes, electric wiring, etc. The surface equipment consists of a boiler house, hoisting plant, and a coal crushing, steel head frame 125 feet in height (see Pl. XXXII, B). Six grades of salt are secured by crushing and screening; as follows:

Lumps. Coarse fragments for salting stock.

No. 2. Passes through $\frac{3}{8}$ inch mesh and caught on $\frac{1}{4}$ inch mesh screen.

No. 1. Passes $\frac{1}{4}$ inch mesh and caught up on 3-16 inch mesh.

"C.C." Coarse chemical. Passes 3-16 inch mesh and caught upon $\frac{1}{8}$ inch mesh.

"F.C." Fine chemical. Passes $\frac{1}{8}$ inch mesh and caught upon 1-16 inch mesh.

"Dust." Everything passing through 1-16 inch mesh.

The plant is located alongside a branch of the Michigan Central Ry. and the company has constructed a line—"The Detroit and Western Ry." from its shaft house to the Wabash, slightly over a half mile to the west. The markets for the salt thus far are mainly Chicago and St. Louis, the salt being used mainly in curing fish, meat and hides, manufacture of ice cream and general re-

frigeration. Henceforth, the mining of rock salt is to be reckoned as one of Michigan's important industries, the only other states producing this material being New York, Kansas, Louisiana, Utah, Idaho and California.

Pigments. Deposits of red and yellow ochre, of sufficient size to be of economic importance, occur in Sumpter township. These represent swamp deposits of iron oxide, transported through the agency of plants and finally precipitated along with impurities of sand and alumina. Iron bearing minerals contained in the soil furnished the original supply, the decay of which led to the formation of iron oxide, which in the presence of the carbon dioxide gas, resulting from plant decay, was converted into the very soluble iron sulphate ($FeSO_4$) or the iron carbonate ($FeCO_3$), which is somewhat soluble, especially in water containing the carbon dioxide gas. In these forms, the iron may be transported to the swamp, where upon standing the carbonate or sulphate is decomposed and a compound of iron, oxygen and water formed, known as hydrous ferric oxide, or limonite ($2Fe_2O_3+3H_2O$). These changes are expressed by the following equations readily intelligible to those having studied chemistry.

$$4FeCO_3+7H_2O+2O=(2Fe_2O_3+3H_2O)+4H_2CO_3$$
$$4FeSO_4+7H_2O+2O=(2Fe_2O_3+3H_2O)+4H_2SO_4$$

When the deposit is sufficiently pure, irregular, brownish-yellow lumps are formed which are known as "bog ore," local deposits of which occur in numerous parts of the township and in an early day were of economic importance. When the deposit goes down in earthy condition, with more or less impurity, it is known as "yellow ochre" and when ground and mixed with oil has value as paint. Upon standing under certain conditions, this form of the oxide is changed to the ferric oxide, hematite (Fe_2O_3), which contains no water chemically united with it, although often mechanically mixed therewith. This has a cherry red color and when earthy is known as "red ochre," valuable also as a pigment. An extensive deposit, mostly of the yellow but with some of the red, occurs a mile west of Martinsville in Sumpter township (secs. 9, 10, 15 and 16), reputed to be a mile square and an average thickness of 6 to 10 feet. It is said to rest upon marl which indicates that it is a younger and true swamp deposit. Other deposits are reported from secs. 6, 18, 20 and 22. Some 7 or 8 years ago a company ("Huron Valley Consolidated Oil and Paint Co."; Thomas W. Boatwright, President.

Ypsilanti, Mich.) was organized to put this material upon the market. Land was purchased and some farms leased and the intention was to erect a factory at Belleville, but there the matter still rests.

MATERIALS AS ABRASIVES.

When examined under the microscope, much of the Sylvania sand is seen to have been secondarily enlarged, crystal faces having formed over the well rounded granules, giving highly perfect edges and points. Such sand is peculiarly well adapted to serve as an abrasive, wherever loose sand can be utilized; as in scouring, sanded surfaces, sand blasting, etc. Along Raisin River, in the neighborhood of the outcrop in Monroe County, the farmer's wives have long known of its superiority over the common sand of the region for scouring kitchen utensils. Owing to its purity, whiteness and sparkle, it has proven popular with the match manufacturers to supply the rough surface placed upon each box. It should make a very superior soap of the *sapolio* type, when supplied in the proper proportions. For use in aquaria and in schools where sand moulding is carried on, the Sylvania has no superior. An exceedingly fine grayish sand obtained from the Huron valley has been placed upon the market and sold locally by Frank Miller, of Belleville. It was advertised as "Deep down Polish" and recommended for iron, tin, brass, copper and silverware. The individual grains can just be detected with the naked eye when spread thinly over a dark surface and when rubbed between the fingers; under the microscope appearing as sharply angular mass of grains, chiefly quartz. The sand probably represents a delta deposit of the Huron during one of the ancient lake stages.

MATERIALS FOR FUELS.

Peat. The waters of the glacial lakes lingered so long over the more poorly drained portions of Wayne County that no extensive beds of peat were able to form. The production of this type of material requires shallow water, or swamp conditions, for the favorable growth of the mosses and sedges (*Sphagnum* and *Carex* principally), and for their subsequent preservation. The sites of the more extensive swamp areas, previously located (see Pl. X), furnish deposits of peat, but are probably of no great thickness, and, at present, of little commercial value. The utilization of peat as a fuel is seriously retarded by the expense of drying, this

being done by the sun in many countries where peat is extensively used as a fuel. For commercial purposes, this seems so far to be impracticable. The production of gas from peat is now possible by placing the partially dried product in an especially designed retort, with a certain amount of air and superheated steam. The by-product is ammonium sulphate ($(NH_4)_2SO_4$), which has high value as a land fertilizer. The use of fibrous peat as litter in bedding stock is also to be strongly recommended. When used as an absorbent for the liquids about the barn yard that are wasted the peat becomes even more valuable than the leached manure itself. A discussion of the occurrence, origin, composition and properties of peat will be found in the Ann Arbor Folio.[6]

Oil and gas. Much money has already been expended in searching for oil and gas in southeastern Michigan, but with practically nothing in the way of direct returns.. As a result of these enterprises, however, we have learned much concerning the geological substructure of this portion of the state, of its water-bearing horizons and through the log of the deep well at Wyandotte in 1887 (Eureka Iron and Steel Works) the presence of rock salt was made known. This discovery has meant more for the industrial development of Wayne County than any reasonable amount of oil and gas could have done. It has also shown that there is no justification for further heavy expenditures in the search for oil and gas, since the rock strata are dipping to the northwestward and these desired products appear to have shifted to the Canadian fields about Leamington. The heavy flows of pocket gas, often encountered when the Antrim shales are penetrated will continue to arouse false hopes and stimulate unwise expenditures in the future as in the past. This gas at times shows pressures of a hundred pounds, or more, to the square inch and if confined properly could be utilized by the farmers for cooking, heating and lighting their homes and in caring for stock. Just over the Base Line in Oakland County, W. J. Purdy has a 110-foot well (SE. ¼ NW. ¼ sec. 25, Southfield township) which has supplied his home with fuel for 16 years, the original pressure being 37 lbs. to the square inch. Under the terms of a lease to outside parties 5 other holes have been drilled, all but one yielding gas. The supply from each well will be exhausted sooner or later, which may be replenished by sinking a new well.

Since fragments of this shale will often burn with flame when placed in the fire, it has been mistaken for coal and efforts made

6. C. A. Davis, U. S. Geological Survey, No. 155, p. 8. See also Report of the State Board of Geological Survey of Michigan for 1906, p. 92 and 1908, p. 205.

to start mining, as reported from near Belleville. As a bed, it contains great quantities of gas, oil and other combustibles, which might be secured by distillation, but which will not become commercially valuable until our present fuel supply is more nearly exhausted. Upon the estate of W. H. Stevens, NW. 1/4 NE. 1/4 sec. 13, Greenfield township, the experiment was tried for a few years of manufacturing lampblack through the incomplete combustion of this natural gas, causing the carbon to be deposited. The experiment was not especially successful and was given up about 12 years ago.

CHAPTER IX.

SUMMARIES BY CIVIL DIVISIONS.

To furnish residents of the county with condensed information relating to their own or neighboring localities and to point out the near at hand illustrations of the various features discussed in the body of this report, it is proposed to devote this chapter to a set of summaries by townships. The classification adopted is genetic, and hence natural, and groups together townships which are related in topography, soils, agricultural products, problems of drainage, water-supply, roads, etc. Most of the townships fall readily into some one of the main divisions, some of them overlap the natural areas so that they combine characteristics of the two and have been placed in the division that appears dominant.

MORAINIC AREAS, UNDULATING SURFACE AND CLAY SOILS.

Northville township. T. 1 S., R. VIII E., (northern part). Named from village when it was detached from Plymouth township in 1897. Township lines were originally surveyed by Alexander Holmes in 1815 and subdivided the same year by Joseph Wampler. Area 18.270 square miles; population 2274. Surface rough with knolls, ridges and depressions strewn with surface boulders; soil mainly stiff clay of glacial origin; many of the hills composed of gravel and sand of the type known as *kames*. The highest elevation in the township (the county as well) lies in the NW. ¼ sec. 6 and equals about 980 feet above sea level; the lowest is at the SE. corner (sec. 13) and is about 715 feet. A broad glacial drainage channel extends southwestward from Northville village, across secs. 3, 4, 9, 8, 17 and 18, floored with gravel and sand, once carrying the drainage of the ice sheets to the southwestward, while the ice was forming the Defiance moraine, lying just to the eastward. This moraine covers conspicuously the eastern half of the township excepting sec. 13 and is drained into the Middle and Upper Rouge. The drainage of the old glacial channel noted is now *reversed* being to the northeastward. West of this channel lies the Northville moraine, involving secs. 4, 5, 6, 7 and 18, many of these hills being kames. The northwestern half of sec. 6 was coated with more or less sand and gravel by the glacial outwash when the ice was

forming this Northville moraine. The Upper Maumee beach cuts southwestward from the NE. cor. sec. 12 to the SW. cor. sec. 14, lying just above the 800-foot contour, showing also in the depression that crosses secs. 1 and 2. The Middle Maumee beach enters the township in the SE. ¼ NE.¼ sec. 12, showing excellent development in sec. 7, Livonia, and passes southwestward just above the 680-foot contour. The Lower Maumee beach enters in the NE. ¼ SE. ¼ sec. 12, lying above and parallel with the 660-foot contour. All three beaches mark the successive shore lines of the old glacial Lake Maumee, consist of disconnected ridges of gravel and sand, approximately parallel and with a NE. to SW. trend. The best place to identify and study them is along the N-S road at the eastern margin of sec. 12. The lowest of the series is the least well defined, which is believed to indicate that it was formed before the middle one and was then washed over while the middle was forming. The outlet of the first of the series of lakes was at Ft. Wayne, Indiana, into the Wabash and later by this and another at Imlay City into Grand River to the site of Chicago. Eastward of these beaches, the land was submerged for a time, including the SE. ½ of secs. 12 and 14 and all of 13, by which the morainic knolls were lowered some and smoothed and the hollows between partially filled. The diagonal road through the SE. corner of sec. 13 is carried upon a still better defined gravel beach, known as the "Belmore" or "Whittlesey beach," the shore line of Lake Whittlesey, which drained across the "thumb" at Ubly, into the Grand. Northville township is well supplied with springs of pure cold water, from its gravel and sand deposits; but getting water from the clay hills is uncertain, the supply being meager in amount and often obtained at considerable depth (8 to 125 feet), invariably hard, but free from sulphur or gas. The bedrock is buried by 90 to 250 feet of clay, sand and gravel ("drift") and consists of light colored shales, sandstone and some limestone, yielding fresh water under sufficient "head" to nearly reach the surface in the depressions. The township was originally forested with a heavy growth of black walnut, beech, maple, oak and hickory, with some birch and bass.

Plymouth township. T. 1 S. R. VIII E., (southern part). Probably named from locality in Massachusetts; established in 1827; included Canton until 1834 and Northville until 1897. Township lines surveyed by Alexander Holmes in 1815 and subdivisions made the same year by Joseph Wampler. Area 19.140 square miles; population 2248. The western half of the township is rough, rolling morainic topography, rendered so by short, slightly curved and ir-

regularly placed clay ridges of the Defiance moraine, with much less gravel than is found in Northville. Field boulders and cobbles strew the surface as they were dropped from the ice sheet. The outwash glacial drainage channel, located in Northville township, extends across sec. 19 giving some sand and gravel; slack drainage and swampy. A somewhat flat ground morainic area extends NE. to SW. across secs. 29, 30 and 31. The Upper Maumee beach, in the form of a disconnected gravel ridge, pursues an irregular, wavy course across secs. 22, 28, 33 and 32 into sec. 5 of Canton, just above the 800-foot contour as it follows along the dissected eastern flank of the Defiance moraine, marking the highest stage of the glacial waters in this region. The Middle and Lower Maumee beaches roughly parallel the Upper, at a distance of 1/4 to 1/2 mile to the eastward, but are disconnected and rather difficult to follow. Their lakeward slopes determine the location and general direction of the 680 and 660-foot contours passing through secs. 22, 27, 28, 33 and 32. A good location in which to see all three is along the N-S highway between secs. 32 and 33, the Upper being seen just where this road is crossed by the diagonal road leading towards Plymouth, while the Lower crosses the town-line at the SE. corner of sec. 32. Along the line of the Pere Marquette Ry., leading west from Plymouth, a good section of the Lower Maumee may be seen 1/2 mile west of the station (SE. 1/4 SE. 1/4 sec. 22), and of the Upper about 3/4 mile further west, with the middle less well defined and lying between. The Belmore or Whittlesey beach, marking the margin of glacial Lake Whittlesey, is a splendidly defined gravel ridge, carrying the diagonal road which passes SW. across sec. 24 to where it is intersected by the diagonal road from the NW. Here the beach leaves the road, curves to westward entering sec. 26 near the NE. corner and pursues a very direct course SW. across secs. 27, 34 and 33. In the village of Plymouth, it has determined the direction of the main residence street and the beautifully graded sites for the homes, at an elevation of approximately 736 feet above sea level. Eastward of the Whittlesey beach, the topography is relatively flat, the soil a gravelly, sandy loam as a result of the delta deposits of the Middle Rouge during the glacial lake stages, involving all of secs. 25, 35 and 36, the greater portions of secs. 24, 26 and 34 and the SE. corners of secs. 27 and 33. Over this delta deposit there occur in secs. 26 and 36 a few low gravel or sand ridges, having a course N. NE. to S. SW., representing bars in the old lake, or washed over beaches of Lake Arkona stage, which were supposed to have been formed before the Whittlesey, an advance of the ice dam then

forcing the water to the Lake Whittlesey level. The highest elevations are found at the NW. corner of sec. 20 and the adjacent NW. corner of sec. 21, along the crest of the Defiance moraine, rising to 880 feet above sea level. Outside the bed of the Rouge, the lowest elevation is at the SE. corner of sec. 36 where it is close to 690, giving an extreme relief in the township of 190 feet. The drainage of the NE. and NW. corners of the township is into the Middle Rouge, the remainder into the Lower Rouge. The bedrock consists of the "Coldwater shales," which are light colored and interstratified with seams of sandstone and some limestone. They are covered by from 90 to 250 feet of clay, sand and gravel, the depth to rock at Plymouth being 100 feet and having an elevation above sea level of about 635 feet.[1] The elevations of the rock surface probably do not differ greatly, apparently rising some to westward, the great differences in the thickness of the rock cover being due mainly to the morainic features noted. So far as known, the water from bedrock is not highly mineralized and contains no notable amounts of gas or sulphur unless the underlying black shales are reached. At Plymouth, the head of this water is about 725 to 735 feet. Over the morainic area, springs occur but not as abundantly as in Northville township, since the gravel hills are not so numerous, and the problem of getting well water is somewhat uncertain. The wells range in depth from 14 to 80 feet and yield a hard water; often abundant but sometimes all too meager. East of the Whittlesey beach the wells are shallow as a rule, 9 to 18 feet, the delta deposit reposing upon the clay and attaining a thickness of some 18 to 30 feet. On the beach itself the gravel is 20 to 25 feet in thickness, yielding a limited supply of hard water, liable to contamination. In section 34, within ¾ of a mile of the Whittlesey beach there occurs a cluster of flowing wells from 50 to 70 feet in depth, rising some two to three feet, containing iron but little other mineral besides and having a temperature of 51° to 52°. The natural forest growth over the morainic, clay areas was walnut, hard maple, beech, whitewood, oak, white ash, rock elm and basswood. Over the sandy gravelly loam areas; elm, black ash, whitewood and hard maple.

Monguagon township. T. 4 S., R. X to XI E., (in part). Passing from the western part of the county to the extreme eastern we have a strip of territory that has much in common with it. This township was named from the old Potowatamie chieftain; was origin-

1. At the cemetery, a driller reports having gone to a depth of 250 ft. without striking rock. If this is not an error it would indicate either a fissure in the rock filled with drift, or a great trough having a depth below the general rock surface of at least 150 feet. Further records are required to settle this point.

ally surveyed by Joseph Fletcher in 1816 and 1817; established in 1827; has an area of 23.355 square miles and a population of 3367. It includes Grosse Isle and some of the smaller adjacent islands. Except for a narrow, sandy strip running southward through secs. 11, 14, 23 and 26, marking the level of the First, or Upper Lake Rouge beach (elevation about 594 feet), the soil of the township is stiff, glacial clay, sparingly strewn with boulders and cobbles and having a gently undulating surface. These undulations are very different in appearance from the ridges and knolls of Plymouth and Northville townships, consisting of approximately parallel, N-S. corrugations in the clay, varying in height from 1 ft. to 12 or 15 ft. These are highest in the vicinity of Trenton where they rise some 28 feet above the river level (elevation 602 feet) and upon the western half of Grosse Isle, gradually becoming lower toward the westward and dying out on the flat till plain just over the township line in Brownstown. In Amherstburg, opposite in Ontario, the same type of ridging is seen, also fading out to the eastward. These ridges were formed at the front of the ice sheet, in some 225 feet of water, the oscillations of the ice wall gouging into the clay of the ground moraine and pushing it up into these regular ridges, dropping on top of them whatever stones were brought to the margin of the ice. These features constitute the Grosse Isle moraine and while they were forming, the shore line of the glacial lake (Maumee) was in the vicinity of Plymouth and Ypsilanti, with its drainage through the Imlay channel into Grand River and Lake Chicago. Some of the depressions between these glacial ridges were occupied by streams of water (the "distributaries" of Taylor) when the level of Lake Rouge fell from its higher to its lower stage (elevation about 590 to 580 above sea level). The current was probably not great and the cutting and deposition were correspondingly small. One of the most conspicuous and typical of these distributary channels leaves the Trenton channel of Detroit River, just north of the Church and Co. abandoned plant, curves to the southwestward, about ½ mile west of Trenton, branches in the SE. ¼ sec. 24, gives off a number of minor branches to the southeastward in sec. 25 and itself joins Brownstown Creek. The "thoroughfare" on Grosse Isle is of the same nature, crossing diagonally to the southwestward and sending off a branch opposite Slocum's Island. Even where not of the nature of distributaries, the ridges control the present drainage, forcing it into the depressions which slope to the southward; good illustrations of very young, consequent streams. The highest land in the township is over the crest of the moraine, along

the road between secs. 6 and 7, reaching approximately 605 feet above sea level, or about 31 feet above ordinary river level. Along the eastern flank of this elevation, at Wyandotte Heights, the First Rouge beach shows somewhat poorly, extending southward through the western part of sec. 5, and southwestward across sec. 7. Just opposite upon Grosse Isle, the same poorly defined, gravel ridge curves about the head of the island. Monguagon township was submerged during the second and third stages of Lake Maumee and during the lives of the entire series of glacial lakes to the first stage of Lake Rouge, when the crests of the higher morainic ridges had emerged from the glacial waters. In spite of this long submergence, conditions were not favorable for the deposition of lake sediments in the form of clay; the glacial clays, cobbles and boulders showing upon the surface. The bedrock consists of Dundee limestone over the northern portion of the township and Upper Monroe dolomite over the southern portion of the mainland and Grosse Isle. Natural outcrops occurred at Sibley, Stony Island and the southern part of Grosse Isle. At the two latter places quarries into the dolomite have been opened and abandoned, while the limestone quarry at Sibley (sec. 7) is in very successful operation. The drift cover increases most rapidly to the northward attaining a thickness of 70 to 80 feet on the town line between Monguagon and Ecorse, and at the head of Grosse Isle. Water is ordinarily obtained from layers of gravel or sand in this drift at variable depths. Springs are not abundant owing to the scarcity of surface gravel and sand deposits. Northward through secs. 25, 24, 13, 12 and 1 there have been strong flows of artesian water, with some sulphur, but practically all have ceased flowing, for reasons not yet positively known. The native forest growth is white and black ash, hickory, walnut, beech, hard and soft maple, elm, basswood, yellow and white oak, whitewood, cottonwood and sycamore.

City of Detroit (City of the "strait") T. 1 and 2 S., R. 11 and 12 E., (in part). Founded in 1701; incorporated as a town in 1802; as a city 1806; charter repealed in 1809 and regranted in 1815. Area approximately 42 square miles; population 465,766. Although in the vicinity of the suburbs, there occurs considerable sand and the type of ridging that accompanies this soil, the city is built upon a broad clay ridge, the Detroit moraine, which appears in the vicinity of Birmingham, passes southeastward, crosses the river to Windsor and continues southeastward across Essex County. The highest elevation in the city is in the vicinity of Voigt Park, out Woodward Avenue near the city limits, where the sand covered morainic surface rises from 636 to 638 feet above sea level, or

some 62 feet above river level. The slope is rather gradual to the southeastward, across Woodward Avenue, in the direction of Elmwood Cemetery, becoming steeper as the ridge narrows and curves slightly to the west of the cemetery. From the city limits, along the crest of the ridge to Gratiot Avenue, the average slope is but 3 feet to the mile, while, beyond to the river, the average slope is about 34 feet to the mile. From the crest of the ridge, the slope is gentle and rather regular to the southeast and southwest. This moraine is believed by Taylor to have been formed *sub-glacially*, (as an "interlobate") along the line of junction of the Huron and Erie lobes of ice during the final stage of the Late Wisconsin, thus accounting for its smoothness and generally subdued character, its breadth, direction, location and freedom from boulders. For a distance of two miles back from the river, across the crest of this moraine and upon its eastern and western flanks, there occurs a series of corrugations similar to those just described in Monguagon township and believed to have been formed in the same way and at the same time. They may be seen typically by passing out Gratiot Avenue to the vicinity of Joseph Campau Avenue and for a distance of two miles from the City Hall out Michigan Avenue by glancing along the side streets. They are believed by the writer to represent the ridges of a water-laid moraine, pushed up by the rythmic movements of the ice-front, extending across the previously formed Detroit moraine, in some 150 to 200 feet of water. Those to the eastward of the crest of the ridge would be arbitrarily assigned to the Huron lobe of ice and those to the westward to the Erie lobe, and hence to be part of the Grosse Isle moraine which passes from the head of that island to Detroit upon the Canadian side of the river. Those ridges for which the Huron lobe was responsible may be connected with the Mt. Clemens moraine, which comes in from the north, but the writer believes that they are directly connected by additional and similar ridges with the Emmet moraine which passes along the eastern shore of Grosse Point township to Milk River Point, there entering Lake St. Clair.

Belle Isle and Isle aux Peches, in the upper Detroit River, probably owe their existence to this same moraine, these islands representing ridges which have been emphasized by stream action, exactly as have those in the lower Detroit region where the correlative moraine crosses the river. The lake chart shows a submerged ridge between Belle Isle and Detroit lying mainly to the north of the bridge and parallel with the others. In the vicinity of the river, some of these ridges have been emphasized by stream action, two of the depressions having furnished the beds of "dis

tributary channels," similar to those described as occurring near Trenton. The Detroit moraine is conceived of as a dam when the waters of the First St. Clair stage were dropping to the next lower stage and through these depressions the currents coursed, carrying much sand and gravel and depositing it in the vicinity of Ft. Wayne and Clark Park in the western part of the city, obscuring the glacial clay. Congress Street, eastward of Woodward, marks the axis of one of these distributary channels and the depression along Labrosse and Baker, to the west of Grand Circus Park, seems to have served as another. Others probably existed in what is now the channel of the river. These ridges subsequently controlled the surface drainage of the region, to a large extent, until deflected by sewers.

The present site of Detroit remained submerged during the entire series of glacial lakes from Maumee to Lundy, 2nd stage. During the 1st stage of this latter lake, the main shore line was just north of the present city limits, in Highland Park, but disconnected sand bars and beaches were being formed in the northern and northeastern portions of the city at elevations of 630 to 636 feet above sea level, showing that the present site was just awash. One of these sand ridges crosses Woodward at right angles between Schiller and Shakespeare streets, on the west and Boston and Chicago upon the east, extending towards Kenwood Station, turning SE. on Oakland and then to the south from Mott as far as Koch, one block east of Woodward. A similar, but not so sharply defined sand belt, has a southerly course, about ½ mile west of the Milwaukee Station and a second roughly parallel and just east of Harper Avenue. To the second stage of Lake Lundy, the water dropped about 25 feet uncovering much of the present city's site, and depositing considerable sand to the north and east of Elmwood Cemetery, between the contours of 610 and 620 feet, along, but mainly to the east of Gratiot. In the opposite part of the city, this shore line (Elkton) is indicated by a sand ridge, having a general easterly course through Beech Hearst, north of Warren Avenue, crossing Warren in the vicinity of 27th Street and continuing as far as 17th, where it dies out, having followed closely the 610-foot contour. In passing around the nose of the Detroit moraine, just west of Elmwood Cemetery, there seems to have been more current action, since we find a cut bluff instead of a sand ridge, well shown between Monroe and Macomb streets, in the vicinity of Joseph Campau Avenue, but continuing eastward and westward for many blocks. Standing at Grand Circus Park and looking out Woodward the cut bluff shows plainly, between

Columbia and High streets, although grading has interfered some with its distinctness. Lake Lundy during both stages drained through Mohawk River eastward while the ice front is believed to have stood in the vicinity of Alpena. Between the contours of 590 and 595 feet, and following Jefferson Avenue quite closely throughout nearly its entire length, another cut bluff marks the water level of the First Lake St. Clair, a little sand having been deposited to the northwest of the Waterworks. In the vicinity of Wayne Street, this water line crosses Jefferson to the westward, intersecting Larned, Congress and Fort streets and roughly following Lafayette as far as the Boulevard. Somewhere along its course this beach line changes to that of the First, or Early Lake Rouge, the waters of which took the sand deposited by the distributaries noted above and heaped it into beach and bar ridges between Clark Park and Woodmere Cemetery, Ft. Wayne and West Detroit. The lower beach of lakes St. Clair and Rouge, just above the 580-foot contour, may be seen in the vicinity of the Waterworks and of Ft. Wayne, but between has been largely obliterated by grading and water front construction.[2] During the existence of the early lakes Rouge and St. Clair, the drainage of Lake Algonquin, their correlative to the north, shifted considerably, being at one time at Trent, Ontario, at Chicago and through these two lakes into Lake Erie. The ice had retreated far to northward, finally withdrawing into the Mattawa and Ottawa valleys. The lower stage of lakes Rouge and St. Clair is correlated with the Lakes Nipissing, the disappearance of the ice in the Georgian Bay region, allowing drainage by North Bay, Ontario. The thickness of the drift ranges from 90 to 160 feet, overlying the bedrock, consisting almost entirely of Wisconsin till, only sparingly charged with rock fragments and so soft that it can be easily cut with a spade. Lenticular masses of quicksand and occasional strata of gravel occur, charged with fresh water. The clay is largely leached of its lime carbonate to a depth of 12 to 15 inches and oxydized often to a depth of several feet. The occurrence of quicksand in the till may make the taller buildings very insecure upon their foundations, requiring the use of piles, or the placing of the supporting masonry upon bedrock. Only a full series of borings should be relied upon to prove the absence of such quicksand deposits at each locality. The bedrock underlying the city is largely limestone of Traverse (Hamilton) and Dun-

2. A good point from which to view this lower beach is just west of the Waterworks, on Park View Avenue, where it may be found about 300 paces toward the river from Jefferson Avenue. From same point the cut First St. Clair beach is in sight upon the opposite side of Jefferson.

dee ("Corniferous") age, the elevation of the surface of which ranges from about 440 to 500 feet over the greater part of the city. In the preliminary borings for the tunnel, "sandstone" is reported in a number of cases, but in view of the full development of Dundee at Oakwood, in Windsor, and at the Ford building, and the fact that no sandrock is to be expected at this geological horizon, the identification may be seriously questioned. The rock surface drops slowly to the eastward being about 457 feet above sea level at the head of Belle Isle, culminating in local depressions in Gratiot and Hamtramck townships. Were it not for the drift, the present site of Detroit would be covered by an average of about 85 to 90 feet of water. In the early days, the settlers obtained their water directly from the river but an increase of population rendered this inconvenient and a system of public and private wells was made use of, these being dug to the water-bearing strata in the sand and walled up with stone. In the summer of 1829 a deep well was sunken by The Hydraulic Company on the south side of Fort Street, between Shelby and Wayne, to a depth of 268 feet and 4 inches in diameter, bedrock ("geodiferous limerock") being reached at a depth of 127 feet. Water in sufficient quantity was not obtained and recourse was again had to the river. A crude pumping plant was begun in 1825 to use the river water, the mains being made of hollowed tamarack logs and the pump was driven by horse power. Water from the bedrock is highly mineralized and contains sulphur. The head in the western part of the city reaches 595 feet, rises to the north and west and drops slowly to the eastward, being about 580 at the Murphy Power Plant, corner Wayne and Congress streets. The temperature of this water may range from 49.5° to 52.5°F., so far as may be judged from the half dozen records available. The original forest growth was white and red oak, ash, whitewood, cottonwood, walnut, butternut, beech, birch, hickory, elm, maple, basswood, cedar, etc.

Grosse Point township. T. 1 to 2 S., R. XIII E., (in part). Named from the large point of land constituting the northeastward corner of Wayne County. Separated from Hamtramck township in 1848, contributed to Gratiot in 1903. Approximate area 11.310 square miles; population 3,579. Surface rendered undulating by the Emmet moraine which follows the shore line, the crest of which rises to 620 feet, near the center of the township, or about 45 feet above the lake level. Drainage is to the southwestward by Fox Creek and to the northeastward by Milk River, lying to the westward and being deflected by the morainic ridges. The

divide between the two streams is poorly defined, in the western part of the township, opposite Vernier. The entire township was subdivided into "French claims," running back from the water front, the direction of which determined the course of the roadways and private lanes, with a NW.-SE. trend, as well as those which crossed the claims at approximately right angles. The exact location of these latter was determined very largely by the NE.-SW. sand ridges of the first stage of Lake St. Clair. Soil mainly a glacial clay, with some surface dressing of sand and a little gravel, but with few cobbles and boulders distributed over the surface. In the northeastern part of the township the moraine lies nearer the lake shore, has been cut into by wave action and there has been a concentration of boulders and cobbles which have partially protected the bank from further encroachment (Pl. XI, B). In addition to this protection, trees, brush, logs, piles, planking and breakwaters have been used to prevent cutting. Since French occupancy, it is estimated that 1000 feet have disappeared to the east of Jefferson Avenue at one place, carrying away a cemetery and orchard; some 130 feet having disappeared during the past 30 years in the vicinity of Vernier Road. Farther north a settler's house had to be moved back twice to keep it from falling into the lake. A fragment of a till ridge, about a mile lakeward from the main ridge of the moraine, lies just eastward of Windmill Point and enters the lake forming a bluff 12 to 14 feet above lake level. Between this point and Fairview Village considerable marshy land and muck borders the lake. In the depression occupied by Fox Creek and Milk River, there is some marsh, mucky soil and more or less lake clay deposited. During the first stage of Lake St. Clair, the township was under water except for an elliptical island, about two miles long by one mile broad, extending from Claireview to Grosse Point Farms, rising about 20 to 25 feet above the water. The narrower portion of this crest existed as a bar during the Elkton stage of Lake Lundy, the main shore line lying some 3 to 4 miles to the west. Upon both the eastern and western slope of this island, sand and gravel ridges were deposited during the life of the two preceding stages of Lake St. Clair, the eastern lying near the present shore line and parallel with it, the western having the same NE.-SW. trend and about a mile to westward, rising to the height of 620 feet. From Grosse Point Farms, two ridges of sand unite from opposite sides of the island and extend W.-SW. as a single ridge, attaining a height of 600 feet, and giving an irregular and more or less disconnected belt of sand to the north of Jefferson Avenue and curving around to

St. Clair Heights. The second stage of the lake formed a sand ridge between 580 and 585 feet, which is followed closely by Jefferson Avenue, especially well shown at Cottage Grove, where the ridge has deflected the course of Fox Creek to the westward and lengthened the stream by some two miles. From Grosse Point Farms, to the northeastward, this beach lies mainly on the lakeward side of Jefferson and has been largely destroyed by wave action of the present lake. A second sand ridge was thrown up by the waves about 1½ miles to the westward, parallel with the present shore to an elevation of 484 to 488 feet above sea level; determining the location of Mack Avenue for its last four miles in Wayne County. This sand is 5 to 6 feet thick, rests upon blue clay, and yields a poor supply of moderately soft water. Obtaining water from the glacial clay is uncertain, requiring depths of 15 to 80 feet; water hard. Rock records are meager in the township, the depth to which ranges from 90 to 160 feet, the extreme southern portion of the township being apparently underlain by limestone and bluish shale (Traverse) and the remainder by the black shale (Antrim). The latter generally gives gas, with some sulphur; the former formation generally yields water more or less charged with salt. The head is insufficient to bring the water to the surface except on the old Woodbridge estate (claim No. 183), just south of the Vernier Road upon Jefferson Avenue, where rock was struck at 95 feet and entered .5 foot, the water rising a foot above lake level, marking the beginning of a belt of flowing wells which become numerous along the lake front in Macomb County. The native timber was elm, oak, basswood, black ash, hickory, sycamore, with some beech, maple and whitewood.

Gratiot township. T. 1 S., R. XII to XIII E., (in part). Named from Col. Charles Gratiot. Established in 1903 from portions of Hamtramck and Grosse Point; area 19.425 square miles; population 1900. Rectangular survey by Joseph Fletcher in 1816; eastern and southern parts of township made up of "French claims" from Lake St. Clair, Detroit River and Conners Creek, causing much irregularity in the direction of highways, both as to their direction and spacing. The soil is very largely a glacial clay, but with relatively few boulders and cobbles strewing the surface and flat, smooth topography, with slopes changing from east, through south around to southwest, directing the drainage to Milk River, Fox Creek and Conners Creek. The township contains the southern extension of the Mt. Clemens moraine, much better defined to the northward, but here a broad, poorly defined swell of glacial clay with no perceptible ridging. It was deposited under water, at a

depth of 165 to 175 feet, the ice margin having here none of the gouging, pushing effect that marked the formation of the Emmet and Grosse Isle moraines. Just northward in Warren and Erin townships, boulders and cobbles are much more in evidence. The main slope of the township is slightly south of east and averages but about 8 feet to the mile, dropping from 629, at the extreme NW. corner (sec. 2), to about 588 along the eastern border. The even topography and clay soil are interrupted in secs. 2 and 11 by an irregular set of sand ridges, some 10 to 12 feet above the general level, representing shore deposits in the early stage of Lake Lundy and more or less modified by subsequent wind action. When the waters of this glacial lake fell to the Elkton stage (about 635 to 610 feet, above sea level), the shore lay to the east of Gratiot Avenue, where on the shallow and gently sloping strand, small, disconnected ridges of sand were formed over an area. $\frac{1}{2}$ to 1 mile broad, reaching from the Base Line to Conners Creek. The wave action does not seem to have been heavy, in part accounted for by the presence of the morainic ridge and island in Grosse Point township. When the water level fell to the First Lake St. Clair stage, wave action continued slight, apparently because the force of the waves was broken to eastward, and a small notch, 12 to 18 inches deep, was cut in the clay, with practically nothing in the way of deposit. This starts just where the Vernier Road joins the Base Line, passes across the claims, veering slightly to the west and curving around to where Mack Avenue crosses Conners Creek. In this vicinity, passing from behind the island above noted, the wave action appears to have been greater and a sandy ridge was formed. The course of this shore feature was mapped before the topographic map was made and was found to be almost exactly parallel with the 600-foot contour, and at an elevation of about 595 feet. Medium hard to soft water is obtained from the sand areas at shallow depths. Over the clay portions of the township hard water is obtained only at variable depths and in varying quantities, depending upon how successfully the water bearing horizons are reached. These wells range from 9 or 10 feet to bedrock, which varies from about 110 feet in the eastern part of the township to 135 in the western, increasing to some 160 or 170 feet at the south. The elevation of the rock surface ranges from 420 to 500 feet above sea level, dropping to about 420, where the depth is greatest to the south of Conners Creek. This rock is mostly black shale (Antrim) and yields gas in small quantities. Ground water nowhere reaches the surface, falling short by some 5 to 20 feet, the head ranging from 600 to 612 feet. The

original forest growth of this region was white and black ash, basswood, white oak, beech, hard maple, butternut and some walnut.

TILL PLAIN AREAS, FLAT SURFACE AND CLAY SOILS.

Canton township. T. 2 S., R. VIII E. Named from city of China. Derived from Plymouth township, established in 1834. Township lines surveyed in 1815 by Alexander Holmes; subdivided in 1819 by Joseph Wampler. Area 35.935 square miles; population 1113. Soil largely a stiff glacial clay; only restricted sand and gravel areas. Although submerged by the glacial lakes Maumee, Whittlesey and Arkona, there are no recognizable lake deposits from their waters. All but about 4½ square miles of the township is remarkably level and flat, left smooth by the Late Wisconsin ice sheet as it retreated from west to east. Two square miles at the northwestern corner (sec. 6 and portions of 5 and 7) are rough and rolling because of the Defiance moraine, formed at the front of the ice sheet during a stage of halt. This crosses from Plymouth, southwestward into Superior township, much of it above the 800-foot level, reaching 850 feet at the extreme NW. corner. This small area has all the characteristics given for Plymouth and Northville townships, of which it is geologically and physiographically a part. The eastern flank of this moraine held back the waters of Lake Maumee during its three stages and more or less continuous ridges of sandy gravel were built along the slope from materials washed out of the clay. The morainic knolls were thus subdued and the slopes rendered more regular as is indicated by the course of the 800, 780 and 760-foot contours. The three beaches cross secs. 5, 6 and 7, roughly parallel, from NE. to SW. and from ½ to ¾ of a mile apart. The first, or upper, is the less well defined and most difficult to follow as it was made when the lake was narrow and wave action relatively slight. It crosses the NW. corners of secs. 5 and 7 and the SE. portion of sec. 6. The third, or lowest, beach is the most direct and continuous, cutting diagonally through secs. 5 and 7, while the middle, lies about half way between these two. The most advantageous point from which to examine the series is at the SE. corner of sec. 6. From a half to a mile SE. of the Lower Maumee, and roughly parallel with it, lies the much more conspicuous and better known "ridge," known as the Belmore, or Whittlesey beach, standing some 10 to 15 feet above the general level, and having an elevation of 735 to 740 feet. Except for short distances at two points, this beach has furnished the site for the diagonal road in

secs. 18 and 19 of Canton and sec. 25 of Superior (Washtenaw County), enters sec. 8 at the SW. corner, crossing the section to the west of the center, then crossing the SE. ¼ sec. 5 and the NW. ¼ sec. 4. Being so typical throughout its course, it may be observed to advantage at any point. It contains some 20 to 25 feet of gravel and sand and furnishes a desirable site for farm buildings, a number of houses in Cherry Hill being so placed. The slope from this beach to the southeastward is regular and relatively rapid to the 720-foot contour and then so gentle as to be barely perceptible to the eye, dropping to about 667 feet at the SE. corner. The drainage is thus deflected eastward into Tonquish Creek, a tributary of the Middle Rouge, and southeastward into the Lower Rouge. From the second stage of glacial Lake Maumee, with drainage at Ft. Wayne, Indiana, into the Wabash and at Imlay City, into the Grand River Valley, the waters are believed to have dropped to the Arkona stage, during which drainage was around the "thumb" directly into the Grand. The level of the lake waters fluctuated and built up ridges from about 695 to 710 feet above sea level, when an advance of the ice covered the tip of the "thumb" again, raised the level of the water to the Whittlesey stage and forced the drainage across at Ubly into the Grand River Valley. The Arkona beaches were thus submerged and to some extent obliterated so that they may be traced often only with difficulty. They pass northward from Dentons through secs. 32, 31, 30, 29, 28, 20, 21, 15, 16, 17, 8, 9, 10, 4, 3, 2 and 1. A good development is seen at the NE. corner sec. 30 and in the NW. ¼ NW. ¼ sec. 1. The Warren, or Forest beach, passes northward through the village of Canton as a moderately well defined gravel ridge, just above the 680-foot contour, crossing through the middle of secs. 34, 27 and 22, fading out for a couple of miles and reappearing in 11, 2, 12 and 1. Some sand was blown, or washed westward from the Wayne beach in Nankin township and forms a thin veneer over the eastern row of sections from north to south. The NE. and SW. corners of Canton township extend into the gravelly sand deltas of the Middle Rouge and Huron rivers, representing deposits formed during the Arkona stage of the glacial lakes. Considered as a whole Canton township is at present the best watered of any in the county, containing the largest number of flowing wells and the best quality of water. These wells lie to the east of the Whittlesey beach, distributed over a belt three miles broad, crossing the township from northeast to southwest. The water ranges from soft to hard, generally contains iron and occasionally some salt and gas derived from bedrock, is obtained from

the drift at depths ranging from 25 to 100 feet; 65 to 75 feet being a common depth. The head ranges from 690 to 720 feet, falling off to the eastward about as rapidly as the surface slope, so that the water rises generally from 2 to 4 feet above the level, and has an average temperature of 51 to 53°F. Shallow wells, requiring pumping, are obtained from the sand and gravel deposits and occasional springs appear. Bedrock records are very meager because of the ease with which water may be obtained from the drift, rendering our knowledge of the nature of the bedrock and its depth incomplete. The NE.-SW. diagonal of the township seems to roughly separate the black (Antrim) shale to the southeast from the Coldwater series of sandstone, shale and limestone to the northwest. The depth ranges from 80 to 100 feet over an E.-W. central strip of the township, deepening to 130, or 140 feet, toward the SE. and NW. The actual elevation of the rock surface over this central strip is about 620 feet above sea level, dropping to 575 feet in sec. 4 and about 535 in sec. 36. The original forest growth was hard maple, beech, oak, whitewood, walnut and butternut over the morainic regions at the NW. corner of the township; over the flatter areas black ash, elm, whitewood, swamp oak, soft maple with some beech, basswood and wild cherry.

Springwells township. T. 2 S., R. XI E., (in part). Name alludes to the abundance of flowing wells. Original survey of boundary lines in 1816, and subdivisions in 1817, by Joseph Fletcher. Line between public lands and private claims run by same surveyor in 1822. Established 1827; contributed heavily to Greenfield township and Detroit, having but 9.830 square miles left; population 1835. Southern portion of the township taken up with French claims from the Rouge, determining the direction of most of the highways. The topography is unusually flat and even, sloping very gradually from an elevation of 610 feet, along the north boundary line, SE. to the level of the stagnant portion of the Rouge, about 574 feet. The drainage to the Rouge is sluggish and the streams largely intermittent. The soil is almost exclusively clay, of glacial origin over the western half of the township, but with few cobbles and boulders. The eastern half of the township has received a deposit of stratified clay which was deposited as a sediment in the waters of the series of glacial lakes. This sediment was derived, in large part, from the underlying till, separated from the sand and gravel by wave action, carried lakeward and deposited in the depression that lay to the westward of the Detroit moraine. The heaviest of this deposit, so extensively utilized in the manufacture of brick and tile, lies between Michigan Avenue

and the Michigan Central Ry. and eastward of the Pere Marquette Ry. From this as a center, it wedges out in all directions and mingles with the glacial clay. When quite wet and worked up by the wheels of vehicles, this type of clay gave almost impassable roads. Boulders are exceedingly rare in the deposit and to be explained as having been drifted in on icebergs floating in the glacial waters. The small "clay dogs," are of the nature of concretions and were formed where found, probably while the clay sediment was accumulating. The township was completely submerged by the glacial waters until the Elkton stage of Lake Lundy, when the extreme NE. corner began to emerge and a sand ridge was formed by the waves and given an E.-W. trend, just south of Holden Avenue and extending for a half mile upon either side of the Detroit, Lansing and Northern Ry. (elevation about 610 feet). During the first stage of Lake Rouge, with the water level at about 595 feet above sea level, a slight notch was cut in the clay, behind the Detroit moraine, very similar to that formed upon the opposite side by the correlative Lake St. Clair. This curves from West Detroit, around to Edward, just south of Michigan Avenue, takes a course slightly south of west across the township, curving southward across the SE. tip of Dearborn township into Ecorse. During this stage of the lake waters a little sand was spread over the clay in the immediate vicinity of Campbell Creek. Water, very rarely anything but hard, is obtained from two horizons and is generally abundant. The upper water stratum is reached at 12 to 30 feet; 15 to 18 feet, being a common depth. The deeper stratum ranges from 75 to 130 feet, approaching bedrock, furnishes a water with iron and sulphur and strong in chlorine, calcium and sulphates, temperature 51° to 53°F., under hydraulic pressure that brings it near, or above the surface, the maximum height reported being 20 feet. In a few instances, considerable salt is present, rendering the water unfit for use, and indicating its derivation from bedrock. The central portion of the township appears to be underlain by the limestone and blue shales ("soapstone") of the Traverse formation; the southern by the greyish limestone of the Dundee (Onondaga) and the northern by the black Antrim shales. The depth ranges from about 90 feet along the northern and southern margins to about 120 to 130 feet across the central portion of the township, indicating that there exists a shallow trough, entering from Dearborn and extending into Detroit. The rock surface in the northern part of the township has an elevation of 510 to 520 feet, dropping to 470 to 480 feet, and then rising along the Rouge to about 500 feet. The original

forest growth over the higher land was beech, hard maple, oak, whitewood, basswood and walnut; over the lower areas elm, black ash, soft maple and poplar.

Ecorse township. T. 2 to 3 S., R. X to XI E., (in part). Named from the Ecorse River, meaning *bark* in French. Made up largely of French claims. Established 1827; contributed to Taylor in 1847. Area 35.410 square miles; population (including Wyandotte) 9398. Although there is a margin of sand along the northern and eastern borders, the large part of the township is a flat, poorly drained till plain, with a stiff glacial clay soil, having only a small deposit of sedimentary clay from the series of glacial lakes that covered the region down to the birth of Lake Rouge. Surface boulders and cobbles are conspicuous only in the SE. corner, where the margin of the Grosse Isle moraine grazes the township. The western town line is remarkably level ranging in 6 miles only from 600 to 604 feet, above sea level, and the slope is gradual to the eastward, down to the river (574 feet), about 4 feet per mile, upon an average. The township is drained mainly by the three sluggish branches of Ecorse River and by short, intermittent tributaries of the Rouge. Both of these streams, as well as Monguagon Creek and the Huron River, show the phenomenon of "drowning," by which is meant that they have marshy banks and unexpectedly deep channels near their mouths, which were cut when Detroit River was practically out of commission and these streams had greater velocity because of their flow to a lower level. This cutting is believed to have occurred during the life of Lake Algonquin when the drainage was either by Chicago, or the Trent Valley in Ontario. The return to the St. Clair—Detroit outlet restored the former level and submerged the lower courses of these rivers. The original banks are still under water about their mouths and so little time has elapsed that they have not yet silted up their channels. Schools in the vicinity of these drowned areas should instruct their pupils as to these conditions since children in wading along the streams occasionally step off the submerged bank and are drowned. Ecorse township did not appear above the waters of the glacial lakes which followed the retreat of the ice from this region, until the level dropped from the Elkton stage of Lake Lundy to the first stage of Lake Rouge, when a poorly defined notch was cut in the glacial clay at an elevation of about 593 to 594 feet. This shore line enters sec. 31, SE. ¼, from Monguagon, curving to the northward through the eastern half of secs. 25 and 24, across the claims for a couple of miles and then veering slightly to westward and curving around

in the NW. corner of the township and across the SE. corner of Dearborn into Springwells township. Very little sand is deposited along its course and only a careful inspection of the flat country will enable one to detect the shore line, which must have been made with little wave action. In dropping from the first to the second stage, the distributary channels in the vicinity of Detroit and Windsor brought down considerable sand and this was worked into a rather well defined beach ridge along the eastern margin of the township, closely following the 580-foot contour.

Upon Brady Island, along its eastern margin, there is a pretty well defined gravel ridge at the right level for this beach. The gravel itself was probably deposited by the distributaries and subsequently modified by wave action. This gravel and sand ridge has obstructed the natural drainage, gives water at shallow depths and is indirectly responsible for much of the malaria and typhoid of the past. Good drainage for the country districts, sewers for Wyandotte and the villages and a closely guarded water supply are imperatively demanded. As is generally the case, getting water from the glacial clay is more or less uncertain, depths of 60 to 80 feet being common. A belt of flowing wells extends along the western margin of the township, the continuation of those from Monguagon, and although all have suffered loss of head and volume a number are still in commission. The water is generally charged with hydrogen sulphide gas (H_2S), often so much so as to be unfit for use. The depth to rock ranges from 70 to 90 feet over the township and so far as known it consists largely of the Dundee (Onondaga) limestone, seen in the Sibley quarry. At the northern end of the township (Oakwood) the elevation of the rock surface is 492 feet above sea level and at the southern margin some 510 to 520 feet, with no marked variation in range between.

Brownstown township. T. 4 to 5 S., R. X E., (in part). Named from Adam Brown, an early settler. Original survey by Joseph Fletcher in 1816 and 1817; established 1827. Reduced in 1842 to add to Monguagon. Area 40.005 square miles; population 2045. Entire township covered with the rectangular survey and only slightly interfered with by the French claims, ordinarily adopted along the main water courses. The highest elevation is in the NW. section (620 + feet), dropping to the SE. very gradually and deflecting the drainage to the Lake Erie level, 573 feet. The streams are of the young, consequent type, intermittent in their upper courses, straight, low banks, marshy, slightly branched. Smith Creek is peculiar in that it parallels the Huron for nearly its entire length and lies so near throughout. Those portions of the

streams below the 580-foot contour owe their position and direction of flow to the distributary channels and the depressions between the ridges of the Grosse Isle moraine. The general topography is flat and the soil is a stiff, glacial clay, as left by the Late Wisconsin ice sheet. For a distance of two miles west of Gibraltar and southward as far as the Huron gentle, parallel undulations of the Grosse Isle moraine are impressed upon the clay and the surface carries boulders and cobbles. These features constitute a waterlaid moraine, formed by an oscillating ice front, as it stood in some 200 feet of water of glacial Lake Maumee. The undulations are most conspicuous in secs. 27, 34 and 35 and grow fainter towards the Huron, giving out completely south of the river and seemingly continuing as a boulder belt. In the NW. corner of the township, some eight square miles of land were covered with sand during the Elkton stage of Lake Lundy, rather pronounced ridging occurring in secs. 9, 16 and 29, as the result of wave and subsequent wind action. The flat topography and clay subsoil have given rise to an extensive swamp in the north half of sec. 8, the southern half of 5 and NW. 1/4 sec. 9. A swamp and marl deposit occurs in NE. 1/4 sec. 28, the amount of marl not being ascertained. From Flat Rock to the mouth of the Huron there is more or less sand deposited along the northern side, or left bank. Some rather pronounced ridging occurs along the railroad (Detroit, Toledo and Ironton) and also just east of the Detroit and Toledo Shore Line at Rockwood, between 590 and 600 feet elevation. This sand was probably deposited by the Huron when the level of Lake Erie corresponded with that of the first stage of Lake Rouge, and was then modified by wave and wind action. A narrow belt of sand at the same approximate level crosses secs. 11 and 14 (Monguagon) just east of the center, diagonally across sec. 23 and continues southward through the western portions of secs. 26 and 35, then following the contour, jumps three miles westward to Flat Rock. There is very little indication along the lake and river shore of the stage of water corresponding to the second stage of lakes Rouge and St. Clair. Small patches of sand, or loamy soil do occur, however, in the neighborhood of the 580-foot contour (secs. 13, 23 and 24; T. 5 S.), and one mile west of Gibraltar (NW. 1/4 NW. 1/4 sec. 1) there occurs a short stretch of gravel beach, at the right level. The SE. point of Brownstown, largely submerged at this stage, received a veneering of black, mucky soil and is still largely swamp.

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greater portion of the township and flowing wells could be numbered by the hundred. However, a steady decline has been in progress and scarcely a one remains that reaches the actual level of the region in which it is located. A few still occur between Flat Rock and Rockwood that rise to the level of flats 3 to 5 feet below the general level, greatly reduced in quantity and head. This water was obtained in close proximity to the rock surface, either just on the rock, just above and a few feet within. The presence of iron and sulphur, along with chlorine, calcium and the sulphates, suggest that it has always come from bedrock. Over the southern half of the township some very heavy flows of similar spring water were common in an early day, but the flow from these has also been greatly reduced. Owing to the nearness of bedrock to the surface in the southern portion of the township (10 to 30 feet, as a rule) the wells are commonly shallow and some of them were reputed to be able to rise 10 to 20 feet above the surface. In the northern part of the township the bedrock lies from 70 to 80 feet below the surface and the wells generally go to this depth. The temperature of the water is very uniform, generally 51° to 52°F., but ranging from 50° to 55°. Over the sand covered regions limited quantities of fresh water are obtained at shallow depths, by reaching the clay. The loss of the flowing water is a serious one to many of the farmers, entailing considerable annual expense and it is hoped that this resource may still be properly conserved. The elevation of the surface of the bedrock ranges from 520 to 530 feet in the northern portion of the township to about 580 feet in sec. 35 (SW. 1/4 SE. 1/4) and about Flat Rock, dropping again some 15 to 20 feet toward the Huron. From the latitude of Rockwood southward, the glacial clay is underlain by the pure white Sylvania sandstone, extending nearly or quite to the mouth of the Huron. The distance down is but 12 to 18 feet, as a rule, and the sandrock is so incoherent that it often causes trouble in the wells. The middle third of the township is underlain by the dolomitic limestones making up the Upper Monroe formation and the high grade Anderdon limestone. The northern 3 tiers of sections must rest upon the Dundee limestone, exposed at Sibley and upon the Macon in Monroe County. The dolomites have been quarried for some years at the quarry W. NW. from Gibraltar (SW. 1/4 SE. 1/4 sec. 35) and reduced to road metal, but this plant was closed down and dismantled, Sept., 1911. It is noteworthy that the flowing wells come from each of the three formations represented, rather than any one, the strongest sulphur and iron waters being derived from the Upper Monroe. This

suggests that the water is conducted through joints and fissures into the neighboring strata and permits the hypothesis that the collecting area lies to the northwest, although this is the direction of dip for the rock strata. The native forest growth consisted, in the main, of white and black ash, hard and soft maple, yellow and white oak, hickory, elm, basswood, walnut, beech, whitewood, cottonwood and sycamore.

DELTA AREAS, FLAT SURFACES; SOIL GRAVELLY, SANDY LOAM.

Van Buren township. T. 3 S., R. VIII E. Named from President Martin Van Buren. Township lines surveyed in 1815 by Alexander Holmes; subdivisions by Joseph Wampler in 1819. Township established in 1835, derived from Huron; area 36.690 square miles; population 1700. Practically all except the NE. quarter of the township was strewn with delta deposits of gravel, sand and silt during the three stages of Lake Arkona, giving a smooth, flat topography, except for the occasional beach ridges. In the western part of the township the thickness of this deposit runs to 15 or 20 feet and where subsequently cut through by the Huron furnishes the conditions requisite for seepage springs along its banks. The gravel becomes finer and finer to the eastward and passes into sand, practically free from pebbles. Two-thirds of the deposits lie to the south of the Huron and appear to have deflected the river some five miles eastward before allowing it to take its natural southeast course to the lake. A small patch of glacial clay occurs just north of Belleville and secs. 2, 3, 10 and 11 have a similar soil, receiving but little of this delta dressing. The general surface slope is southeastward, average rate 7½ feet per mile, dropping from 720 feet to about 656. The Huron has deeply incised the country, the banks at Rawsonville being 55 to 60 feet high and diminishing slowly eastward. The township lies outside of the morainic areas but has a belt of boulders and cobbles, one to two miles broad, passing southward along the central meridian as far as Belleville, where it appears to turn westward to Rawsonville, entering Washtenaw County. This belt may be traced northward across the county and is believed by the writer to mark a temporary halt of the ice sheet, previous to the formation of the delta and incident to the final retreat from the region of the Late Wisconsin ice sheet. The three water levels of Lake Arkona are indicated by disconnected and often poorly defined gravelly-sand ridges, ranging in elevation from about 707 to 694 feet above sea level, having a generally southerly course and swinging to

the southwest. The upper Arkona ridge cuts across the southern half of sec. 18 to the eastern side and follows the section road north to Denton, passing through the western part of the village and furnishing a site for the cemetery. The middle ridge shows itself in the western part of sec. 30, was destroyed by the Huron, crosses sec. 17 and follows northward about a mile east of the highest Arkona as a faint feature, turns westward and crosses the Michigan Central Ry. near the center of sec. 5. The lowest ridge crosses the south half of sec. 31 and passes northward in secs. 32 and 29 until it encounters the old bank of the Huron that marks the Lake Warren stage. North of the river, it has faint expression across sec. 16, until it reaches the NE. ¼ when it deposited a little gravel upon the lakeward side of a prominent off-shore bar of the Middle Arkona stage, which curves northeastward across the NW. corner sec. 15 into sec. 10, passing northward through the western part and enters sec. 4 at its SE. corner, curving westward. These ridges, although generally of slight expression, are responsible for slack drainage and swampy soil in secs. 7, 8, 17 and 18. The advance of the ice front from a position some 25 miles NE. of Bad Axe to the vicinity of Port Huron caused the water level to rise to the Whittlesey beach in Washtenaw County and to flood the entire township, as it had been flooded by Lake Maumee during pre-Arkona times. No extensive delta formed at this stage, otherwise the Arkona beaches would have been buried and obliterated and when the water subsided to the Lake Wayne stage (elevation about 650 feet), the fall must have been rather rapid, otherwise the Arkona ridges would have been leveled. The Warren, or Forest beach (elevation 682) appears in the southern half of sec. 33, passes northward through the western part of sec. 28, reappears on the opposite side of the Huron in the northern portion of 22, is poorly represented in secs. 14 and 11, entering sec. 3 at its SE. corner and leaving from the NE. ¼ NW. ¼. Where the beach is not well shown cobbly areas occur as though the waves had removed some soil, leading to a concentration of these rock fragments. During the Warren stage the ice dam is believed to have been in the vicinity of Alpena, the drainage around the "thumb" into Grand River Valley, and thence into Lake Chicago, the advance of ice forcing the water to this level from that of Lake Wayne as previously noted in the Arkona-Whittlesey episode. The glacial water history for this region may thus be summarized: Lowest stage Lake Maumee (760 feet); Middle stage Lake Maumee (780 feet); three stages Lake Arkona, (705, 698, 692 feet); Lake Whittlesey (730 feet); Lake Wayne (650 feet); Lake

Warren (680 feet). The key to this peculiar behavior is furnished by the manner of ice retreat which seems to have consisted of a relatively long retreat each time followed by a short advance. During the Lake Warren stage, the Huron formed the terrace upon which the village of Belleville is situated the southern bank of the river, 10 to 12 feet high, cutting diagonally across sec. 30, southern half of 29, SW. 1/4 sec. 29 and curving southward through the eastern half of sec. 33. The delta and beach deposits furnish a liberal supply of water at shallow depths, 7 to 30 feet, and numerous seepage springs, as noted, occur along the banks of the Huron and its tributaries. The water is generally hard, but sometimes medium and soft. In the clay areas, NE. 1/4 of the township, it is necessary to go 50 to 125 feet, or even more, to get a supply; generally abundant, but sometimes meager. A splendid supply of flowing water (temperatures 51° to 52°F.) singularly soft, is obtained from the drift at Denton and two miles eastward by going from 70 to 80 feet in general, but occasionally from only 40 to 50 feet. According to George W. Lyons, driller, just over the rock lies a bed of "hard-pan," from one to ten feet thick, itself overlain by more or less gravel. The head of this water closely approaches 700 feet, dropping to eastward, indicating a source from the upland to the westward. The depth to bedrock varies from 80 to 90 feet at the NW. and SE. corners to about 120 feet at the center of the township, dropping then rapidly to the east and northeast. A very decided trough extends N. and S. through the eastern double strip of sections, some 170 to 180 feet deep, reaching its greatest depth at the SW. corner of sec. 1, where the rock elevation is about 495 feet, or 78 feet below the ordinary level of Lake Erie. The trough may have been gouged from the soft black shales by the action of the ice sheets, although its axis extends *across*, instead of *with* the direction of the main ice movements. The axis of the trough extends through secs. 12, 13 and 24, with elevation of 495 to 500 feet, rapidly rising some 40 to 50 feet. In the vicinity of Belleville, the shale rock ("slate") is reached at a depth of 99 to 118 feet, giving an elevation of the rock surface of some 560 to 580 feet above sea level, approximating Erie level. In passing to Denton it rises to about 620 feet, while toward the southeastward it remains approximately horizontal. A belt of black (Antrim) shale (sometimes mistaken for *coal*) underlies most of the township, passing from NE. to SW., and giving more or less gas. The Coldwater formation, consisting of light colored shale and sandstone, appears to cross the NW. corner, while the Traverse (limestone and "soapstone") crosses the SE. corner. The original

forest growth was hard and soft maple, white ash, beech, elm, white oak, whitewood, basswood, sycamore, hickory; with some red and swamp oak, black ash, butternut and walnut.

Livonia township. T. 1 S., R. IX E. Supposedly named from the province in Russia in an effort to find names not duplicated elsewhere. South and east township lines surveyed in 1816 by Joseph Fletcher; north and west lines in 1815 by Alexander Holmes; north line corrected in 1819 by Fletcher; township subdivided in 1816 by Fletcher. Established in 1835, derived from Nankin. Area 35.960 square miles; population 1365. This township shows the greatest variation of any in its physical features and soils and is crossed by the greatest number of the glacial lake beaches. The prevalence of considerable delta material, derived largely from the Middle Rouge during the Lake Arkona stages, as well as that brought down during this and other lake stages by minor streams, places Livonia in a class with Van Buren just described. The soil is very largely a gravelly, sandy loam, except for some ridges; sloping quite gradually from the Whittlesey beach (elevation 736 to 739), which cuts diagonally through secs. 5 and 7, southeastward to 634 (SW. cor. sec. 36), giving an average slope in this distance of some 16 feet to the mile. Westward of this well defined gravelly beach ridge the soil is a loamy clay, with some minor ridges of the Defiance moraine showing in secs. 5, 6 and 7 which were not obliterated by the waters of the glacial Lake Maumee. The drainage is mainly eastward by Bell Branch of the Upper Rouge, the southern portion of the township draining into the Lower Rouge. Bell Branch seems to be deflected eastward by the Rouge delta deposits to the southward, just as noted for the Huron in Van Buren, its southern branches being turned *northward* by the ridges of sand and gravel in sec. 21. Two boulder belts cross the township which probably mark the temporary positions of halt of the front of the Late Wisconsin ice in its retreat from west to east. The most westerly of these belts enters from the eastern part of Plymouth township, crossing secs. 18, 7, 8 and 5, heading towards Farmington. The second passes from N. to S. just east of the central meridian of the township, not especially well defined, and giving an indication of morainic topography in sec. 15. The bulk of the delta deposit was laid down in the SW. ¼ of the township, extending from eastern Plymouth, and reaches 12 to 15 feet in thickness, consisting of gravel and pebbly sand resting upon glacial clay, furnishing water to shallow wells and favorable conditions for seepage springs wherever the porous deposit is cut by the streams. A splendid flow of this nature is

found near the SW. corner of sec. 29; others in sec. 16 and vicinity. The gravelly sand and loam in the NW. ¼ and the northern half of the NE. ¼ is partly delta and partly shore material, from which shallow water is obtained with less certainty, often necessitating the sinking of wells to depths of 45 to 85 feet. Crossing the township in a general NE. to SW. direction there are 10, more or less distinct, beach ridges of either sand or gravel, or a mixture of the two. This series comprises all but the three youngest of the entire series of Huron-Erie beaches. The Upper Maumee cuts across the extreme NW. corner of sec. 7, entering from sec. 12 of Northville, and gives a sandy belt just above the 800-foot contour, upon both sides of the clay ridge crossing sec. 6. The Middle Maumee (3rd in age) lies ¼ mile to the eastward in sec. 7, where it shows fine development, approaches the higher in sec. 6 and lies just above the 780-foot contour. The Lowest Maumee enters sec. 7 (NW. ¼ SW. ¼) from the SW., just above the 760-foot contour, giving it a somewhat straight course to northeastward, except where destroyed by stream action, entering Oakland County very near the NE. corner sec. 6. In subsiding from the Middle Maumee stage, the waters fell to the Arkona stages, before returning to the Whittlesey beach already noted in secs. 5 and 7. The Upper Arkona is the best defined of the three in this region, lying just westward of the 700-foot contour. It enters the NW. ¼ sec. 30, passes northward through sec. 19 (being pushed eastward by the delta deposits) and then follows a very direct NE. course through secs. 18, 8, 5 and 4, parallel with the Whittlesey and about ¾ mile SE. of it. It is especially well developed in the northern half of sec. 4. Fragments of the Middle and Lowest Arkona are to be seen from ½ to ¾ mile to the eastward, separated rather poorly from one another and the next lower Warren beach; owing to the relatively rapid surface slope on the delta. The latter enters the SE. ¼ SE. ¼ sec. 31, curves northward through Nankin village, between secs. 29 and 30, gives some irregular ridging in sec. 20, crosses 17 diagonally, curves through the southern half of sec. 9, showing fine expression, crosses the NW. ¼ sec. 10 and leaves the county at the NE. ¼ NE. ¼ sec. 3. Quite a well defined gravel ridge appears in the NW. ¼ NE. ¼ sec. 32, at an elevation of about 670, crosses the eastern half of sec. 29, the western half of secs. 21 and 16, deflecting the drainage of the tributaries of Bell Branch. This ridge is too low for the Warren beach and too high for the Wayne, and may represent a bar in the former, or a hitherto unrecognized stage of the glacial waters, which left its record just here because of the abundance

of pebbles. Traces of the same stage are seen in sec. 10 (NW. ¼ SW. ¼ and NE. ¼ NE. ¼), and at the NW. ¼ NW. ¼ sec. 2. The Wayne beach is well defined in secs. 28 and 21, leading to the village of Livonia, but at an elevation some 7 to 8 feet too high (662 to 665 feet). Being a sand ridge this extra height may be accounted for as due to wind action. The ridge drops somewhat in sec. 15, but remaining about the 660-foot contour and flattens out to the northeastward. The Grassmere beach, representing the first stage of Lake Lundy, is indicated by some disconnected sand ridges in the SE. ¼ of the township, ranging in elevation from about 635 to 645 feet. The best defined and most continuous ridge begins in the NE. ¼ of sec. 27, curving into sec. 22, giving a branch to the northward and curving sharply to eastward across the southern half of secs. 23 and 24. Scraps of the same beach ridge occur northward on the town line in secs. 13 and 12, extending over from Redford. A limited area of flowing wells, with low head, occurs in the eastern part of sec. 18 and adjacent portion of 17; depth 45 to 55 feet; temperature 51° to 52°, somewhat soft. A "deer lick" is said to have been located on the flats at the NE. corner of sec. 7. In the SE. quarter of the township, where the delta deposit is thinner or entirely absent, it is necessary to enter the clay for water to depths of 60 to 100 feet or more, securing water reported as both hard and soft. The rock varies from 60 to 100 feet over most of the township, being more deeply buried in the NW. corner (110 to 120 feet) because of the rise in the surface levels. The elevation of much of the rock surface ranges from 550 to 580 feet above sea level, rising possibly 100 feet towards the NW. The NE.-SW. diagonal of the township approximately marks the line of separation between the Coldwater formation, of light colored shale and sandstone, and the black (Antrim) shale, carrying more or less gas. Penetrating this shale and entering the underlying Traverse, gives salt water and going still deeper into the Dundee limestone gave small quantities of a very thick black oil, serviceable as a lubricant (NE. ¼ NW. ¼ sec. 34 and SW. ¼ NW. ¼ sec. 36). The original forest growth was mainly elm, white and black ash, hard and soft maple, beech, oak and whitewood.

Dearborn township. T. 2 S., R. X E., (in part). Named from General Henry Dearborn. Township lines and rectangular subdivisions surveyed in 1816 by Joseph Fletcher; established 1833. The rectangular survey is rendered irregular by the military reservation about the village of Dearborn and the French claims along the Rouge and its northern branch. Area 34.410 square miles;

population 2761. Except where dissected by the three branches of the Rouge, the township is mainly level and flat, lying mostly between the contours of 600 and 630 feet. The NW. corner, however, rises to 639 feet and the SE. drops to 589, giving an extreme relief, aside from the river bottom, of 50 feet and a general southeasterly slope. The soil and subsoil are mainly a stiff glacial clay, relatively free from boulders and cobbles, which was formed beneath the Late Wisconsin ice, without any pronounced halt. Over the center of the township and towards the south and southeastward, the clay received a veneering of sand during the Elkton stage of Lake Lundy, some prominent ridges being formed as the result of wave and subsequent wind action. These dune ridges, some of them rising to 620 feet, have furnished sites for the irregular, diagonal roads leading from the village of Dearborn. This sand was brought to the lake very probably by the Rouge and originally deposited as delta sand, afterwards being worked shoreward by the waves. From secs. 4 and 5 southward to 32 and 33 there occurs a veneering of sand up to 8, 10 and 12 feet in thickness, with only very minor ridging, lying between the contours of 615 to 625 feet, which probably represents, in part, a delta deposit of the earlier stage of Lake Lundy, somewhat modified by wind. The three branches of the Rouge: Upper, Middle and Lower, enter the township with banks varying in height from 20 to 30 feet, and with average fall of 8 feet per mile, measured from the Whittlesey beach along their respective valleys. Within the limits of the township the banks become lower and the fall becomes much less, for the main Rouge amounting to less than 6 inches per mile. With these three streams converging and flowing so much below the general level, the surface drainage is good. Over the sandy portions of the township, water is obtained from shallow wells (10 to 25 feet) by entering the clay far enough to obtain a suitable reservoir. The water thus obtained is not usually very abundant, is generally hard, but occasionally soft. In the clay districts obtaining water is uncertain both as to amount and depth. In the eastern part of the township the water rises to near the surface, under artesian pressure, but does not flow. A heavy flow of sulphur water was struck in the village of Dearborn, depth 290 feet, showing a head of 635 to 640 feet. This water probably comes from a channel in the Monroe formation, instead of from a single water bearing stratum, and even neighboring wells might yield no such flow. The depth to rock ranges from 60 to 80 feet in the northern tier of sections, deepens from 120 to 140 feet across the central strip, and rises southward from 80 to 100 feet again

in the vicinity of sec. 34. The village of Dearborn lies over the axis of a shallow trough in the rock surface, which enters from southern Nankin and extends across Springwells, spreading out beneath Detroit. The elevation of the bottom of the trough seems to range from 500 to 470 feet above sea level as it crosses the township from west to east. Toward the north, the rock surface rises from 550 to 560 feet and southward from 525 to 535 feet. The bedrock is probably very largely the Traverse formation, consisting of alternating layers of limestone and bluish shale ("soapstone"). The records of gas found in the wells along the northern border of the township along with the adjacent region suggest that this portion is underlain by the black (Antrim) shale. Upon the sand areas the main forest growth was originally black and white oak, black and white ash, elm, basswood, butternut, and chestnut, with some hard and soft maple and beech. The clay supported in the main a growth of elm, black ash, oak, beech, hard and soft maple, basswood and hickory with some walnut.

BEACH AND DUNE AREAS; HEAVY RIDGING AND SANDY SOILS.

Sumpter township. T. 4 S., R. VIII E. Named from Gen. Thomas Sumter. Township lines surveyed by Alexander Holmes in 1815; subdivisions in 1819 by Joseph Francis; reserve by James H. Mullett in 1843. Township established in 1840, derived from Huron and for a time called "West Huron." Area 37.285 square miles; population 1228. The northern half of this township extends into the delta formation of the Huron, during the Arkona stage, and geologically belongs with the preceding main division of townships, being covered with a pebbly sandy loam. This deposit is highest and presumably thickest towards the NW. corner of the township (elevation 692 feet), thinning towards the east, southeast and south; the pebbles becoming finer and finer and passing into sand. The general slope is southeastward, dropping to 626 feet at the SE. corner, or at the average rate (neglecting the sand ridges) of about 8 feet to the mile. The NE. and SW. corners of the township are almost exactly the same level, if we neglect the valley of the Huron, which there grazes sec. 1. The drainage is either into Swan Creek direct, or into its tributary Disbrow Ditch. The westernmost portion reaches Stony Creek and the extreme northern strip is drained into the Huron, the upper courses of the streams being largely intermittent. The township is crossed from NE. to SW. by the beaches of three of the series of glacial lakes, the lower two of which (the Wayne

and Grassmere) show considerable wave and subsequent wind action, the ridges formed being distributed largely along the southern and eastern strips of sections. These ridges are sharply defined, generally less than a mile long, irregularly placed and extend in no uniform direction. Since some of them may be of the nature of bars and others of dunes, it is difficult to separate the two sets from one another. The slack drainage caused by these sand accumulations is responsible for a rather extensive swamp in sec. 29, which extends southward into sec. 32. Numerous deposits of ochre ("bog iron ore") in the central and western sections indicate that the swamps were more extensive formerly than at present. The Warren, or Forest beach, is not well defined, consisting of a faint, gravelly sand ridge, just above the 680-foot contour. It cuts across the northern half of sec. 7 to the NE. corner, curves across the southern half of sec. 5 and cuts the NW. ¼ of sec. 4, entering Van Buren township. Some little clay soil and loam are found in secs. 25, 26, 35 and 36. Throughout the gravel and sand areas shallow wells (6 to 16 feet) yield a supply, generally sufficient, of water variously reported as hard, soft and medium. Sometimes all that is necessary is to dig or drive to the vicinity of the underlying clay; when greater supplies are desired, a reservoir in the clay is made into which the water collects from the overlying sand and gravel. In the SE. quarter, where the sand is largely concentrated into ridges, it is necessary to enter the clay to depths ranging from 30 to 70 feet, in some cases water being obtained from a stratum of gravel just over bedrock. Water somewhat sulphury and rising under artesian head to near surface. In 1903 one flowing well existed at the SW. ¼ SE. ¼ sec. 25. The rock ranges in depth from 35 feet at the SE. corner of the township to about 100 feet at the NW. corner, so far as may be judged from the meager records. The actual elevation of the rock surface does not vary greatly from 560 to 580 feet above sea level. The underlying rock of the SE. half is probably Dundee limestone, similar to that seen on the Macon, Monroe County, and at Sibley; the NW. half is probably the limestone and bluish shale ("soapstone") of the Traverse formation, which is liable to yield water more or less charged with salt. The original forest growth corresponded very largely with that of Van Buren over the northern area and much scrub oak over the heavily sanded areas, along with some chestnut.

Huron township. T. 4 S., R. IX E. Named from the river which received its name from the tribe of Indians that occupied the region. West township line surveyed in 1815 by Alexander

Holmes; north, east and south lines in 1816 by Joseph Fletcher; subdivisions in 1816 by Fletcher. Township established in 1827 and later reduced to form Van Buren (1835), Romulus (1835), and Sumpter (1840). While the latter was known as "West Huron," this township was known as "East Huron." Area 35.790 square miles; population 1690. The township as a whole is characterized by sandy soil, the western half carrying numerous, irregularly placed sand ridges; the NE. ¼ carries an even dressing of sand without ridging; the SE. ¼ contains minor knolls and ridges of sand, considerable loam and some clay. Isolated patches of clay and loam occur also in the other quarters of the township. The general slope of the township is from NW. to SE. (about 650 to 600 feet), or at the average rate of about six feet to the mile, neglecting the ridges. Between the SW. and NE. corners of the township there is slight difference in elevation. The Huron crosses the township diagonally and receives most of the drainage. through short, largely intermittent streams. The banks are dropping to the eastward, being about 34 feet above the bed at New Boston and 20 to 22 feet at Flat Rock. The SW. corner of the township is crossed by one branch of Swan Creek and receives drainage from a few sections. In spite of the sand covering, a belt of boulders and cobbles ("Scofield boulder belt") may be traced from N. to S. along the Pere Marquette Ry., believed by the writer to mark a stage of halt of the ice sheet in its final retreat across the township. The ice front at this time may then have served as a dam for the waters of Lake Maumee during one of its temporary stages. The further retreat of the ice to the NE. allowed the glacial waters to drop to successively lower levels and the township began to emerge during the first stage of Lake Lundy, when the waves threw up the ridges across the NW. corner of the township (elevation about 635 feet). The sands upon drying were heaped still higher by the wind and scattered over the clay surface. In secs. 7 and 18 some of the ridges are high enough to have been formed during the preceding Lake Wayne stage, rising about 650. In the vicinity of Willow and Waltz the strongest of the sand ridges have a NW.-SE. trend, from 615 to 625 feet in elevation, and were apparently formed by wave and wind action during the Elkton stage of Lake Lundy. The shore line extended NE. through secs. 22, 23, 24 and 13, but made no definite ridge. Two sets of wells are used; the shallow (7 to 20 feet) from the sand deposits and the deeper wells into the clay, ranging ordinarily from 30 to 85 feet, and in some cases entering rock. The former wells are hard to soft, the latter yield water with some sulphur.

The depth to rock ranges from about 20 feet in the neighborhood of Flat Rock, to 80 to 90 feet in the NW. corner. The actual elevation of the rock surface is about 580 feet above sea level, near Flat Rock, dropping from 10 to 20 feet only towards the northwest and not varying greatly from horizontality. The well records give limestone only for the bedrock, not distinguishing between the real limestone and the dolomitic variety. The SE. portion of the township must, however, be underlain by the Upper Monroe dolomites, with their strong sulphur waters and the northwestern portion by the Dundee limestone, with its occasional suggestion of oil. The test well at the NE. 1/4 of sec. 17 proved a disappointment. The township consisted largely of the "oak openings" of pioneer days.

Romulus township. T. 3 S., R. IX E. Named presumably from the reputed founder of Rome. West township line surveyed in 1815 by Alexander Holmes; north, east and south township lines by Joseph Fletcher in 1816; subdivisions by Fletcher in 1817. Township established in 1835, being derived from Huron. Area 35.660 square miles; population 1538. Romulus township is closely related to Huron just described so far as soils, topography and geological history are concerned. It, however, contains much more clay and loam over its eastern half; flat and poorly drained by intermittent streams giving an easterly or southeasterly course to the Ecorse and Brownstown Creek. The Scofield boulder belt enters from Huron township at about sec. 32 and takes a N. NE. course across the center of the township, leaving at sec. 3, marking a position of halt of the ice front. The belt is about 1½ miles broad and contains boulders and cobbles, especially abundant in the northern half of the township. Neglecting the sand ridges the general slope is to the southeastward, from an elevation of approximately 670 feet to 620 feet, or about six feet to the mile as in Huron township. The NE. corner of the township is about 25 feet lower than the SW., the latter having been built up by delta material from the Huron, during the glacial lake series of the Arkona and Warren stages. A set of sand ridges between secs. 29 and 30 may be traced northward through the western part of the village of Romulus (sec. 17), veering NE. into secs. 9 and 4, and ranging from 655 feet to 670 in elevation. These ridges were apparently formed by the waves of Lake Wayne and then heaped up by wind into dunes. A second set of similarly formed dunes marks the first stage of Lake Lundy, some 25 to 30 feet lower. They cut through the southern half of secs. 31, 32 and 33 and then beginning in the SW. 1/4 sec. 34 form a peculiar series of

approximately parallel NW.-SE. ridges as far as the eastern margin of the village of Romulus and determining the course of the diagonal road through secs. 34, 33, 28 and 21. From Romulus NE. the ridging is less well defined but may be seen in secs. 10, 11, 12, 1 and 2, separated by areas of clay and loam, suggesting weaker wave action than that in the SW. 1/4 of the township. The SE. 1/4 of the township was submerged but the water was only 10 to 15 feet deep and received some sprinkling of sand over much of the clay. The slack drainage to the westward of these heavy ridges was responsible for swamp conditions in the past in which muck soil was formed. Such a deposit lies between secs. 5, 6, 7 and 8, the muck sometimes taking fire and burning to a depth of 6 to 8 feet. The sand of the NW. portion of the township is slightly pebbly, suggesting that the ancient delta of the Huron may extend this far east and north. Most of the wells are of the shallow, sand type, 8 to 20 feet, furnishing limited quantities of hard, medium and soft water. When the quantity is insufficient, deeper wells are sunk and this is invariably demanded in the clay and loam areas, and where the sand is too thin to furnish water in quantity. The wells of this character range, in general, from 40 to 80 feet and the water is more or less impregnated with iron or sulphur, especially when obtained from near bedrock. In 1903 only one flowing well existed in the township, NW. 1/4 NW. 1/4 sec. 36; depth 48 feet to "hard pan." The bedrock is buried by 60 to 140 feet of clay, gravel and sand, deepening from SE. to NW., the actual elevation not differing greatly from 520 to 560 feet above sea level. The SE. corner is probably underlain by the Dundee limestone, which gives traces of gas and oil in a few wells; the remainder of the township has the Traverse formation for its foundation, consisting of limestone and shale ("soapstone"), the water from which gives some salt. The deep well put down upon the Twark farm (SE. 1/4 NW. 1/4 sec. 12) reached rock salt at a depth of 925 feet and penetrated successive layers of salt and lime to a depth of 1820 feet.

Taylor township. T. 3 S., R. X E., (in part). Named from Gen. Zachary Taylor. Township lines and subdivisions surveyed in 1816 and 1817 by Joseph Fletcher. Established in 1847, being derived from Ecorse. Area 23.825 square miles; population 1238. The township is flat and sand covered in large part, receiving its deposits during the life of Lake Lundy, both stages. Isolated patches of clay and loam occur and a strip of stiff glacial clay extends along the very flat eastern boundary, which ranges in elevation from 600 to 604 feet in the six miles. This clay area is

part of the till plain which covers the greater portion of Ecorse township. The western boundary ranges from 620 to 630 feet, the slope being eastward and averaging from 5 to 7 feet to the mile. The northern half of the township is drained eastward into the Ecorse, the southern half by three drains, somewhat south of east, into Brownstown Creek. A set of short, disconnected sand ridges passes from N. to S. through the center of the township, lying mainly eastward of the central meridian, and formed during the Elkton stage of Lake Lundy, at an elevation of 610 to 620+ feet. The N. to S. road through secs. 16 and 21 was evidently shifted ¼ mile west of its proper position in order to get the advantage of this sand belt. Some ridging occurs in the eastern part of secs. 20 and 17 and runs through the northern part of secs. 8 and 9. The sand along the western strip of sections may represent blown sand from the Elkton shore and also that deposited in the shallow waters of the first stage of Lake Lundy. The sand areas, especially where deepest, yield water at depths of 7 to 20 feet, ranging from hard to soft, and often sufficient for farm purposes. The clay wells range from 60 to 100 feet, yielding water charged with some iron and sulphur, under artesian pressure. In 1903 flowing wells were found at the SW. ¼ SW. ¼ sec. 34; SW. ¼ SW. ¼ sec. 28; NE. ¼ NE. ¼ sec. 15; NE. ¼ NE. ¼ sec. 10; belonging to the belt of flowing wells passing northward from Brownstown and Monguagon, through Ecorse. The depth to rock ranges from 60 feet at the SW. corner to 90 feet at the NW., the shallower having a surface elevation of about 550, the deeper an elevation of about 535 feet above sea level. At the SE. corner, the rock surface drops to about 620 feet. From all the information available, the bedrock is largely limestone of the Dundee (Onondaga) formation, similar to that seen at Sibley. The Traverse probably crosses the NW. corner giving alternating limestone and shale ("soapstone"). The water from it is not highly charged with either salt or sulphur. After penetrating the limestone, the Upper Monroe dolomites are reached which invariably yield water highly mineralized and charged with sulphur.

Nankin township. T. 2 S., R. IX E. Named from city of China. Township lines surveyed in 1815 by Alexander Holmes and Joseph Fletcher; subdivided in 1816 by Fletcher. Established in 1829; derived from "Bucklin" and originally included Livonia. Area 35.940 square miles; population 3966. The eastern and southeastern portion of the township extends into the flat till plain type of topography, with soil of loam or glacial clay, upon which have been superposed some minor ridges of sand, as the result of wave

and wind action. The NW. corner of the township extends into the delta region of the Middle Rouge (Arkona and Warren stages) and is coated with a pebbly sand, similar to that described for Livonia to the northward. Between these two areas extends a broad belt, 3 to 4 miles broad, from NE. to SW., of heavy sand. more or less ridged, especially along the eastern margin of the belt. The general slope of the township is from NW. to SE., dropping from about 693 to 626 feet, above sea level, or at an average rate of about 8 feet to the mile. The NE. corner of the township is about 28 feet lower than the SW. corner (667-639 feet). The drainage is eastward (Middle and Lower Rouge) the streams being more or less deflected by the sand accumulations. The Scofield boulder belt, one to two miles broad, crosses the middle of the township, from N. to S., lying mainly to the eastward of the middle meridian. Many of these boulders and cobbles have been collected and utilized in foundations. During the Maumee, Whittlesey and two higher Arkona stages, the township was completely submerged by the glacial waters. When the level had fallen to the lowest Arkona stage, a poorly defined sand ridge was built across the NW. 1/4 of sec. 6, at an elevation of about 693 or 4 feet above sea level. An advance of the ice front is then believed to have forced the water to the middle stage of Lake Arkona, raising it some 7 to 8 feet. At the time of its next recession, a drop to about the level of 650 feet occurred and the broad sandy beach of Lake Wayne was formed with elevation of 655 to 650 feet, except where wind blown to greater height. Ridging occurred north and northeastward of the village of Wayne in secs. 28, 27, 22 and 23, reaching northward into 14, 15 and 10. marking the approximate shore line of the lake waters. During this stage the lake extended around the "thumb," the ice dam being some 25 to 30 miles NE. of Bad Axe, but the drainage is believed to have been into the Mohawk, near Syracuse, N. Y. An advance of the ice front, until it again covered the tip of the "thumb," forced the water up some 30 feet to the level of Lake Warren, and the drainage was shifted to the Pewamo, Ionia and Grand River valleys into Lake Chicago. This increased elevation brought the level to about 680 feet, extending across the NW. 1/4 of sec. 6, very near the Lowest Arkona, but without leaving a very definite record. The sand found along the N.-S. road between secs. 5 and 6, 7 and 8, may represent bar deposits in Lake Warren, or possibly a temporary shore line corresponding to that observed northward in Livonia township at this same approximate level. In subsiding from the Warren stage, during which time the Wayne

beaches were submerged, the water dropped to the Lundy stage and made a series of sand ridges in secs. 35, 26 and 25, extending to the village of Inkster and reappearing again in secs. 1 and 2. The most of the sand ranges in elevation from 635 to 640 feet, above sea level, but some of it was heaped into still higher dunes by wind action. The slack drainage caused by the sand deposits is responsible for an extensive swamp, involving some 160 acres, but originally much more extensive, in the vicinity of the SE. ¼ of sec. 18, extending into secs. 17, 19 and 20. The sand that mantles the clay attains a thickness of 10 to 12 feet and shallow wells are the rule over the western half of the township. These yield sufficient water, as a rule, which ranges from hard to soft. About the center of the township and over much of the eastern half, where the sand is scantier, it is necessary to enter the clay and to varying depths (40 to 140 feet), securing water which carries some salt and sulphur. In the SW. corner of the township, the artesian pressure is sufficient to bring the water very near or quite to the surface causing flows to the west and northwest of Wayne. Upon the old Proctor Estate also, a well has been flowing (NW. ¼ NW. ¼ sec. 15) for a number of years. The depth to bedrock is about 100 feet at the SE. corner and about 125 feet at the NW. corner, with a trough-like depression of 120 to 160 feet cutting across the southern half of the township. Just south of Perrinville the well records indicate that the rock rises to 50 feet, forming a rock knoll on the northern side of the depression and attaining an elevation of about 585 feet. Just west of Inkster the rock surface in the trough-like depression referred to drops to about 480 feet above sea level, this being a part of the same feature which enters from Van Buren and extends into Dearborn, probably representing an old pre-glacial drainage valley, modified by ice action. The rock elevation at the extreme SE. corner is about 520 feet, and about 560 feet at the NW. corner. The bulk of the township appears to be underlain with the black (Antrim) shales ("slate"), which give more or less gas when entered. The SE. corner is probably the Traverse formation of limestone and light colored shale ("soapstone"), which generally yields water containing some salt. The original forest growth was white, yellow and black oak and whitewood, some chestnut, over the "oak openings;" beech, elm, hard and soft maple, ash, basswood on the lower land; some hickory and walnut on the flats.

Redford township. T. 1 S. R. X E. Named from the ford of the "Rouge," original name being Pekin. Township lines and sub-

divisions surveyed in 1816 by Joseph Fletcher. Established in 1829, being derived from "Bucklin" township. Area 35.680 square miles; population 2176. Although almost all of the SE. ¼ of the township is clay soil, of the flat till plain type, the bulk of it is strewn with sand, much ridged in parts, which places it geologically with the preceding townships of this division. Even over the sand region, isolated patches of clay and loam make their appearance. Neglecting the ridges of largely wind-blown sand, the general slope of the township is southward, dropping from the highest elevation 668, on the Base Line, sec. 1, to about 618, near the center of the southern boundary line; or at the average rate of about 8 feet to the mile. The SW. corner is 39 feet lower (668-639) than the NE. corner, and the SE. corner lies 30 feet lower (651-621) than the NW. corner, while the drop near the middle of the township from N. to S. is 37 feet (659-622), or about 6 feet to the mile. The surface drainage is entirely into the Upper Rouge, by means of short, more or less intermittent tributaries. The rise of land in the NE. corner of the township is due to the crossing there of the Detroit moraine, which runs from Birmingham to Detroit and was formed *sub-glacially* between the Erie and Huron lobes of the Late Wisconsin ice sheet. This feature deflects the drainage to the SW., the average slope amounting to about 9 feet to the mile in the NE. ¼ of the township. Although morainic, the surface was very smooth and received a surface dressing of sand during the three stages of the two glacial lakes, Wayne and Lundy. The shore lines, beach ridges, bars and dunes of the two can not be clearly separated although with the help of the contour map the most prominent may be identified. The older of the two lakes (Wayne) was responsible for the ridging seen in secs. 1, 2, 11 and 12 and for a gravelly soil; the result of wave action on the till, seen about the SW. corner of sec. 12. The heavy sand ridges in the vicinity of Sand Hill, as well as those to the west and south, with a general N. to S. trend, are to be referred to the Lake Lundy, first stage. The sand was in part washed directly from the till, and in part delivered to the lake by the Upper Rouge, the mouth of which was in the vicinity of the present village of Redford. The waves of this lake built up ridges to a height of 635 to 640 feet. The most prominent of these dunes are seen in secs. 7, 8, 9, 10, 11, 15, 16, 20, 21 and 29. As a further result of wave and wind action, a dressing of sand was spread over the general surface of the country obliterating most of the glacial clay. This general deposit reaches a thickness in places of 10 to 12 feet and furnishes well water at shallow depths (10 to 20 feet), the water

ranging from hard to soft, insufficient to abundant. Where the soil is clay or loam, and where the sand deposit is thin, it is necessary to enter the glacial deposit known as till and depths of 25 to 80 feet are required to obtain a sufficient supply. This water is often charged with gas and mineral ingredients (sulphur, salt, etc.) from the underlying bedrock, although it may be derived from beds of gravel and sand. The rock itself must sometimes be entered a few feet especially in the SE. ¼ of the township in order to insure a sufficient quantity. These deeper wells furnish water under artesian pressure in all cases, rising to near the surface but not actually flowing. The depth to bedrock ranges from 80 to 100 feet over the township and, although some of the well records indicate differently, the bedrock is very probably nearly all black shale (Antrim formation), which so commonly yields temporary flows of gas, often under great pressure when first struck. The salt reported in some of the wells in the southern portion of the township, in which direction the shale thins out, is probably derived from the underlying Traverse. The elevation of the rock surface at the SE. corner is not far from 550 feet above sea level; rising slightly towards the NW. The original forest growth was beech, hard and soft maple, black and white ash, elm, walnut, hickory, oak and basswood.

Greenfield township. T. 1 S., R. XI E. Name alludes to the appearance of the fields. Township lines surveyed in 1816 by Joseph Fletcher; subdivisions in 1817 by Fletcher. The SE. quarter of the township includes the "Ten thousand acre tract," surveyed in 1816 by Fletcher and sold to provide the territory with a courthouse and jail. Established in 1833, being derived from Springwells. Area 34.782 square miles; population 4995. Although much of the southern third of the township is glacial clay or loam, the bulk of the township is veneered with sand, much of which has been heaped into conspicuous ridges. The clay is of the till plain type and practically free from surface boulders. From NW. to SE. the township is crossed by the broad, smooth swell of clay which constitutes the Detroit moraine. The highest elevation noted is at the NW. corner (668 feet above sea level) and following along the axis of the moraine drops to about 630, at the SE. corner, or at an average rate of 4¾ feet to the mile. The slope to the NE. and SW. from the axis of the moraine is considerably more rapid, deflecting the drainage accordingly by many, short intermittent streams, those to the south of the moraine going to the Rouge; those to the north to Conners Creek, the moraine serving as the divide. Just upon the crest the drainage is slack and an

extensive marsh enters sec. 5, from 32 of Royal Oak township (Oakland County), extending into sec. 4. Along the western town line the descent is from 668, at the NW. corner to about 618, at the SW. corner, 50 feet in the 6½ miles, or at the average rate of nearly 8 feet to the mile. The higher land caused by this morainic extension across the township formed a broad peninsula during the Lake Wayne and Lake Lundy stages of the glacial lakes, before which time the township was submerged and after which it was dry land. The first of these lakes threw up a series of beach and bar ridges, from the tip of the peninsula in sec. 20, around on the eastern margin through secs. 21, 10, 9 and 4, at elevations ranging from 655 to 665 feet, above sea level. The westernmost two of these approximately parallel ridges may be traced rather continuously for some 4 to 5 miles, the lower and outer is more scrappy and irregular, curving through the SE. ¼ of sec. 20 and across the western half of 21 into sec. 10. As the water rose from the level of Lake Wayne to that of Warren, owing to an advance of the ice front, these beaches and the NW. ¼ of the township were again submerged and the crest of the moraine here strewn with sand, which is slightly pebbly in places. The level of the lake waters subsequently fell to that of Lake Lundy, first stage, and formed a complicated set of irregular ridges in the vicinity of Palmer Park, at elevations ranging from 635 to 645 feet. A sand ridge of this stage, some two miles in length, crosses Woodward Avenue in Highland Park, between Highland and Glendale avenues. Irregular ridging and small amounts of gravel occur to the southwest between Woodward and Grand River, as in SE. ¼ sec. 28; SW. ¼ sec. 28; SE. ¼ sec. 29; westward through sec. 30. In receding from the first stage to the second, or Elkton stage, a somewhat poorly defined and disconnected sand ridge was formed at an elevation of about 610 to 612 feet, extending eastward through the southern margin of sec. 31 and the northern portions of secs. 5, 4 and 3 of T. 2 S., R. XI E. As in the case of the other townships of this class, the sand strewn portions yield water at shallow depths (6 to 18 feet), which ranges from hard to soft, is sometimes sufficiently abundant, at other times scanty in amount. In entering the clay for water, depths ranging from 25 to 135 feet are required, approaching the bedrock. In general, this water is hard but, at times, surprisingly soft; abundant as a rule, but sometimes the head is insufficient to bring the water to the surface, rising usually from 12 to 20 feet of the ground level. When the bedrock is entered, gas often accompanies the water, along with more or less sulphur and iron. By entering

CHAPTER X.

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BY PROFESSOR AMADEUS W. GRABAU OF COLUMBIA UNIVERSITY, NEW YORK CITY.

INTRODUCTORY.

From the collections so far made, about 80 species of invertebrates have been identified. This is by no means a complete list of the species of this fauna; there is a considerable number of species still unidentified, on account of their fragmentary character, while future collections will undoubtedly increase the total number.

In the present report, the species are discussed briefly;* their illustration and full description with discussion of variations and relationships will appear in the monograph on the Traverse fauna of Michigan, which is in preparation, since these fossils are intimately related to those of the other Middle Devonic beds of Michigan. In the monograph, the "Dundee" of Northern Michigan will also be discussed. Much of the details, therefore, on which the present report is based is here omitted, but will be included in the final discussion.

SUMMARY OF THE FAUNA.

The order of arrangement of the classes and genera is that followed in Grabau and Shimer's North American Index Fossils.

INVERTEBRATA.

Class I. PROTOZOA.

None have been recorded from the Michigan beds so far, though in the closely related Columbus limestone of Ohio, *Calcisphaera robusta* Williamson is abundantly represented, often making up

*For descriptions and illustrations of the common forms, see Grabau and Shimer, North American Index Fossils, 2 vols. This report was submitted in 1910. Since then further study has shown that some of the species listed herein are new, but since it is not possible to give at present a complete revision, it is thought best to publish this preliminary report as written. The full discussion of the Michigan Devonic faunas will appear in due time.

to bedrock, which may reach 180 feet. When so obtained the water is generally hard and abundant and, except in the quite shallow wells, only slightly affected by seasonal variations. In entering the rock (limestone or shale), water is obtained often charged with gas, sulphur or salt. In a few instances it is surprisingly soft. In all the deeper wells the water rises under artesian head and may come to within 4 to 5 feet of the surface, but nowhere flows, within the limits of the township. The bedrock is deeply buried by the so-called "drift," ranging from 140 to 160 feet in the western part of sec. 5, where there appears to be a decided depression in the rock surface, the elevation of which is approximately 450 feet above sea level, rising to about 480 feet along the southern township line. The original forest growth was oak, elm, soft maple, black ash, basswood, sycamore and some beech.

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masses of the rock. This fossil closely resembles the organs of fructification of the freshwater stonewort, or Chara, with which it is sometimes identified. It is a nearly spherical body 1 mm. in diameter, and banded by nine spiral ridges.

Class II. PORIFERA.

This class is likewise unknown, so far, in the Dundee of Michigan, but in the Columbus limestone of Ohio it is represented by *Receptaculites devonicus* Whitfield. (Pal. Ohio VII., pl. VI., fig. 10).

Class III. HYDROZOA.

Division HYDROCORALLINES.

This division, represented by a number of genera and species in the Columbus limestone of Northern Ohio, is more sparingly represented in the Dundee of Southern Michigan. From the collections so far made, the genus *Clathrodictyon* has alone been identified. This is represented by a species closely related to, if not identical with, *Clathrodictyon cellulosum* Nicholson and Murie, characterized by the coarseness of its meshwork, and common in the Onondaga limestone of Canada, and occasionally occurring in New York.

In Ohio, the following species have been recorded from the Columbus limestone:

Actinostroma nodulatum (Nicholson).
Stylodictyon columnare Nicholson.
Stromatopora granulosa Nicholson.
S. ponderosa Nicholson.
S. sanduskyensis Rominger.
S. substriatella Nicholson.
S. (Syringostroma) densa Nicholson.

Class IV. ANTHOZOA (Corals).

This class is fairly well represented in some parts of the Dundee, though it is not known to form reefs, such as are characteristic of the Onondaga of Western New York and of the Jeffersonville limestone of the Falls of the Ohio. As will be shown later, the horizon of the Dundee is probably above that of the coral reefs of the Onondaga, a fact further emphasized by the marked dis-

similarity of the coral faunas of the two regions. The species so far obtained from the Dundee of Southern Michigan are as follows:

Genus ZAPHRENTIS Rafinesque.

Zaphrentis convoluta Hall.

This appears to be the most abundantly represented form in Southern Michigan. It is a rapidly expanding curved cone showing the tetrameral arrangement of the septa by the septal striae on the outside of the coral, and characterized by uniting and more or less twisting septa. The fossula is scarcely indicated, though in a few cases, it is discernable. The species is close to Streptelasma. It has been found in the Sibley quarry in beds: A. (6 ft. bed), B. (7 ft. bed), D. (5 ft. bed), E. (6 ft. limestone), I. (9 ft. bed) and elsewhere.

Zaphrentis prolifica Billings.

This species is similar to the preceding, and when the calyx is filled by matrix, can scarcely be distinguished from it. The septa are less strongly twisted, often scarcely at all, and the fossula is well developed. This probably occurs with the preceding, though none of the specimens in the collections I have examined appear to conform to it; but it has been reported from the Dundee of Southern Michigan. It is not uncommon in the lower Traverse of Northern Michigan.

Zaphrentis gigantea Lesneur.

This large species, characteristic of the Onondaga of Western New York and of the Falls of the Ohio, has been reported from the Dundee of Michigan and the Columbus of Ohio. Its cylindrical growth, large size, well developed tabulae which bend down marginally, and well marked fossula are distinctive characteristics. At present, no specimens of this species are contained in the collections of Dundee limestone fossils.

Zaphrentis corniculum E. and H.

This has been recorded from the Dundee of Michigan and the Columbus of Ohio.

Other species of Zaphrentis obtained from the Columbus limestone of Ohio are: *Z. edwardsi* Nichols and *Z. wortheni* Mich.

Genus AULACOPHYLLUM E. and H.

Aulacophyllum sulcatum E. and H.

This species, common in the Jeffersonville limestone of the Falls of the Ohio and also found in the Hamilton group, is sparingly represented in the Dundee of Southern Michigan. It is characterized by the converging septa on either side of the well developed cardinal fossula, in which a thin cardinal septum occurs. The species also occurs in the Columbus limestone of Ohio.

Genus CYSTIPHYLLUM Lonsdale.

Cystiphyllum vesiculosum Goldfuss.

This species is represented mostly by medium-sized individuals, most of the specimens collected being much worn. The cysts are large and the form moderately tapering. No specimens of the size of the prevailing Hamilton form have been found so far.

The species is common in the Onondaga of New York, Canada, and the Falls of the Ohio. It occurs in the Columbus limestone of Ohio, where another, smaller species, with fine cysts, *C. ohioense* Nicholson, also occurs. The latter species has not yet been found in Michigan.

In the Dundee of Southern Michigan, *C. vesiculosum* has been found in the Sibley quarry in Bed A (6 ft. bed), B (7 ft. bed), D (5 ft. bed), I (9 ft. bed) and above, as well as in some of the other horizons.

Genus ACERVULARIA Schweigger.

Acervularia rugosa E. and H. (*Cyathophyllum rugosum*).

This species is not uncommon in the Dundee of Southern Michigan. It has been obtained from 15 to 20 ft. above the bottom of the Sibley quarry in bed I (9 ft. bed) and in bed A (6 ft. bed). It has also been found more generally distributed.

This species occurs in the Sellersburg (Hamilton) limestone of the Falls of the Ohio and in the Columbus limestone of Ohio. It has not been reported from any horizon in Western New York. The species seems to be represented in the Traverse of Northern Michigan, where *Acervularia davidsoni* is the common reef coral. The separation of Acervularia from Cyathophyllum, merely on the ground of the possession of an inner wall is ill advised, since Acervularia has no true inner wall. It seems likely, with our

present knowledge, that both *Cyathophyllum rugosum* and *Acervularia davidsoni* belong to Acervularia, and that they are closely related.

Acervularia davidsoni is a characteristic Hamilton species of Michigan, Iowa, and westward. The genus as such seems foreign to the true Onondaga fauna, and the occurrence of *A. rugosa* in the Dundee and Columbus seems to argue for a post-Onondaga age of these formations. This idea is borne out by the fact that the species occurs in post-Onondaga beds (Sellersburg or Lower Hamilton) at the Falls of the Ohio. The origin of the genus seems to be a western one.

Genus PHILLIPSASTRAEA d'Orbigny.

Phillipsastraea gigas Owen.

This species with calices 20 mm. in diameter has been reported from the Dundee of Michigan, but seems to be confined to the northern area. No specimens have been observed in our collections. It is also a typical Hamilton species in Michigan, Ohio, and the Falls of the Ohio, but in New York and Canada it seems to be confined to the Onondaga.

P. verneuilli E. and H.

This form, with smaller corallites, (10 to 15 mm. in diameter), has been reported from the Onondaga of Canada and the Dundee of Michigan, but appears also to be confined to the northern Dundee. It is likewise reported from the Hamilton of Thedford, Ontario, but this identification needs verification.

Genus ERIDOPHYLLUM E. and H.

Eridophyllum verneuillianum E. and H.

This form occurs in the Columbus limestone of Ohio, and will probably be found in the Dundee of Southern Michigan. I have not seen it among the collections.

E. colligatum (Billings) has been reported from Northern Michigan, and occurs in the Jeffersonville of the Falls of the Ohio and the Onondaga of Canada.

Genus SYNAPTOPHYLLUM Simpson.

This genus differs from the preceding in the absence of the central wall, but agrees with it in the connections between corallites.

Synaptophyllum simcoense Billings.

A small part of a colony of this species has been obtained from the Sibley quarry. It is not abundant but characteristic. The diameter of the corallites is about 4 or 5 mm. It occurs in the Columbus limestone of Ohio, the Onondaga of Canada and Western New York, the Jeffersonville of the Falls of the Ohio, and the "Dundee" or Mackinac limestone of Northern Michigan.

Genus FAVOSITES Lamarck.

Favosites emmonsi Rominger.

This species, with tubes 1 to 1½ mm. in diameter, and crowded tabulae seems to be represented in the Dundee of the Sibley quarry. It is not an abundant form, but is most characteristic of the Onondaga of Western New York and Canada. In Ohio, it occurs both in the Columbus and the Delaware. At Louisville, Ky., it is found in the Jeffersonville beds, and in Northern Michigan in the Mackinac limestone. It has also been recorded from Iowa.

Favosites turbinatus Billings.

This species is the most abundant of any in the Dundee of Southern Michigan. It is of turbinate form, curved, and resembles in outline some Cyathophylloid coral or the mold of some large pelecypod shell. The tabulae of our specimens are rather distant, as are also the mural pores.

The species occurs pretty generally distributed through the Dundee of the Sibley quarry. It has been collected from Bed I (9 ft. bed) and from the 12 ft. bed above the lower 20 ft. bed.

This species is found in the Onondaga of Canada and New York. and in the Columbus of Ohio. It is, however, more distinctively a Hamilton type, occurring in that formation in New York, Ohio. Louisville (Falls of the Ohio), Thedford, Ont., and the Traverse of Michigan.

Other species of Favosites found in the Columbus limestone of Ohio are: *F. basaltica* Goldfuss; *F. hemispherica* Yand, and Shum.; *F. invaginata* Nich.; *F. pleurodictyoides* Nich.; and *F. polymorpha* Goldf. *F. hemispherica* also extends into the Hamilton.

Genus CLADOPORA.

Cladopora cryptodens (Billings) (?)

This is a round-stemmed, branching species, the branching being chiefly a bifurcation. The branches are from 5 to 10 mm. in diameter, and the corallites are scarcely curved. Tabulae few and incomplete. The identification of our specimens with Billings' species is provisional. The specimens are all broken, showing the corallites but not their orifices. They were found in Bed I (9 ft. bed) and in the 12 ft. of beds above the lower 20 ft.; also in the upper 5 ft. of the lower 20 ft.

The species is widely distributed, occurring in the Onondaga of Canada, New York, the Falls of the Ohio, and in the Mackinac limestone of Northern Michigan. Many other species have been obtained from the Mackinac limestone, but no other from the Dundee or Columbus.

The following table shows the distribution elsewhere of the corals obtained from the Dundee of Michigan and the Columbus of Ohio.

TABLE LXV.—SUMMARY OF THE CORAL FAUNA.

	Dundee of Michigan.	Columbus of Ohio.	Jeffersonville of Kentucky.	Onondaga of New York.	Onondaga of Ontario.	Mackinac Limestone.	Sellersburg of Kentucky.	Hamilton of New York.	Hamilton of Thedford, Ont.	Hamilton of Ohio.	Traverse Group of Michigan.	Mid Devonic of Iowa.
1. *Zaphrentis convoluta*	X						?				?	
2. *Z. prolifica*	X	X			X	X	X		X		X	
3. *Z. cornicula*	X	X		X	X	X	X		X	X		
4. *Z. edwardsi*		X										
5. *Z. gigantea*		X	X	X	X	X		X				X
6. *Z. wortheni*		X										
7. *Aulacophyllum sulcatum*	X	X	X									X
8. *Cystiphyllum vesiculosum*	X	X	X	X	X	X	X	X	X	X	X	X
9. *C. ohioense*		X					X			X		
10. *Hadrophyllum d'orbignyi*		X					X			X		
11. *Cyathophyllum zenkeri*		X			X				X			
12. *C. robustum*		X	X					X	X			
13. *Heliophyllum halli*		X	X				X	X	X		X	X
14. *H. confluens*		X					X	X	X		X	
15. *Acervularia rugosa*	X	X				X	X				?	
16. *A. davidsoni*	?						X		X	X		X
17. *Stylastraea annae*	?	X										
18. *Phillipsastraea gigas*					X	X	X			X		
19. *P. verneuilli*					X	X			X			
20. *Eridophyllum verneuillianum*		X			X	X	X					
21. *E. strictum*		X			X		X		X			
22. *E. colligatum*		X			X	X						
23. *E. simcoense*	X	X	X	X	X	X						
24. *Aulopora cornuta*		X			X	X	X		X			
25. *A. filiformis*		X			X							
26. *A. tubiformis*		X						X	X		X	
27. *Syringopora hisingeri*		X	X		X	X						
28. *S. maclurii*		X			X	X						
29. *S. tabulata*		X					X					
30. *Favosites basaltica*		X									?	
31. *F. hemispherica*		X	X	X	X		X			X	X	
32. *F. invaginata*		X										
33. *F. pleurodictyoides*		X										
34. *F. polymorpha*		X										
35. *F. turbinata*	X	X		X	X		X	X	X	X		
36. *F. emmonsi*	X	X	X	X	X	X				X		X
37. *F. limitaris*		X				X		X			X	
38. *Michelina convexa*		X	X		X	X						
39. *M. maxima*		X										
40. *M. cylindrica*		X	X			X						
41. *Cladopora cf. cryptodens*	X		X		X	X						
42. *Alveolites squamosus*		X	X		X	X						
43. *Trachypora elegantula*		X					X	X	X	X	X	

A study of this table which is based on the best available data, shows some interesting results. Of the 43 species listed, 8, or 18.6 per cent., are known elsewhere only from the Hamilton beds; while 10, or a little over 23 per cent., are elsewhere in the eastern province known only from the Onondaga. One of these, however, *Aulacophyllum sulcatum*, is found also in the post-Onondaga beds of Iowa. The other Onondaga species include, moreover, some of the most characteristic species of Eridophyllum, Synaptophyllum, Syringopora, Michelinia, Cladopora, and Alveolites. On the other

hand, it should be noted that it is just these species that are sparingly represented in Ohio; and that only two of them, *Synaptophyllum simcoense* and *Cladopora cryptodens,* occur in the Dundee of Michigan, the first represented by one small specimen, the other doubtfully identified. Moreover, it is these species which may still be found among the coral fauna of the Traverse Group when the study of it is completed, and too much weight should therefore not be placed on this apparent preponderance of Onondaga types. Among exclusively Hamilton species, such characteristic species as *Heliophyllum halli, Heliophyllum confluens, Aulopora tubaeformis,* and *Trachypora elegantula* occur. Of other species generally most characteristic of the Hamilton fauna occur: *Zaphrentis prolifica, Heliophyllum halli, Acervularia rugosa;* and, doubtfully, *A. davidsoni, Favosites hemispherica, F. turbinata,* and *F. limitaris.* On the other hand, species more characteristic of the Onondaga fauna are: *Zaphrentis gigantea, Phillipsastraea gigas, P. verneuilli;* various species of Eridophyllum, Synaptophyllum, and Syringopora; and *Favosites emmonsi.* All of these, however, have been found in typical Hamilton strata. Such typical Onondaga species as *Favosites epidermatus, F. canadensis, Cystiphyllum sulcatum, Acrophyllum oneidaense, Amplexus yandelli, Chonophyllum magnificum,* etc., are wanting. While not conclusive, the evidence of the coral fauna points to a higher horizon than typical Onondaga for the Columbus of Ohio and the Dundee of Michigan, and its closer affiliation with the Hamilton of the eastern province.

Class V. BRYOZOA.

Bryozoa are common in the Dundee of Michigan, some parts of the coarser limestones (calcarenites) abounding in fragments of Fenestella and others. Owing to their fragmentary character, only a few have been identified so far.

Genus FENESTELLA Lonsdale.

Various species of this genus seem to be represented among the fragments, including, apparently, *F.* (*Semicoscinium*) *planidorsatum* Ulrich, also found in the Sellersburg of the Falls of the Ohio.

Genus CYSTODICTYA Ulrich.

Cystodictya gilberti (Meek).

This species, originally described from the Columbus limestone of Ohio, and abundant in that horizon as well as in the overlying

Delaware, is very common in the Dundee of Southern Michigan, occurring in nearly all the outcrops. It is readily recognized by its flat, repeatedly branching stems, and the rapidly increasing number of rows of apertures and separating ridges. The species occurs in the Hamilton (Sellersburg) of the Falls of the Ohio and of Indiana.

SUMMARY OF THE BRYOZOA FAUNA. So far as studied, the Bryozoa indicate a closer relationship of the Columbus and Dundee to the Hamilton than to the true Onondaga. The most abundant and most typical species, *Cystodictya gilberti,* is elsewhere found only in the Hamilton.

Class VI. BRACHIOPODA.

Genus STROPHEODONTA Hall.

Stropheodonta inaequiradiata Hall.

This typical Onondaga species is represented by a few individuals from the Sibley quarry. It is recognized by its coarse, unequal striae and moderate convexity of the pedicle valve. It occurs in the Columbus of Ohio and is known from the Onondaga of New York and Quebec, and appears to be represented in the Devonic of Nevada.

Stropheodonta dundeense sp. nov.

This species is extremely convex, of the average size of *S. demissa,* but with the striae crowded, and often fasciculate. It resembles somewhat a diminutive *S. hemispherica,* but its convexity is too great for it to represent the young of that species. From *S. inaequiradiata* it differs in its greater convexity, and in the more crowded condition of its striae. It is not unlike some of the extreme forms of Stropheodonta from the Hamilton of Missouri. In the Sibley quarry, this species is most abundant in beds G (6 ft. bed) and I (9 ft. bed), and again in the 12 feet of the strata above the lower 20 feet.

Stropheodonta hemispherica Hall.

This large, convex Stropheodonta is abundant in the Dundee of Southern Michigan. Often it is extremely convex and large, but there are many small or half grown individuals. The brachial valves are very gently concave in the younger part, and then become

abruptly bent or even geniculate. The striae are sometimes fasciculate, but not sharp, as in *S. demissa*. The median septum of the brachial valve and the cardinal septum are well marked. The pedicle valve is uniformly and strongly convex, often with a median ridge-like accentuation, and sometimes with rude irregular folds in addition. It occurs throughout the series of strata in the Sibley quarry, and has been noted in the other outcrops, and in the equivalent beds near Windsor, Ontario, as well as in the Columbus of Ohio. Elsewhere this species occurs in the Schoharie and Onondaga formations, having been found in New York, Ontario, etc.

Stropheodonta concava Hall.

This species seems to be represented by a number of specimens with the characteristic sharp striae and the strongly muscular impressions of this Hamilton species. It is found in several of the beds in the Sibley quarry (Bed G, and the bottom 20 ft. bed), and occurs also in the Columbus limestone of Ohio. In New York, it is chiefly confined to the Hamilton, where it abounds, though it has been reported also from the Onondaga. In Indiana it occurs in the Sellersburg and Jeffersonville.

Stropheodonta costata Owen.

This species, probably the *S. erratica* of Winchell, is represented by a few individuals easily recognizable by their small size and coarse plications. It is an abundant form in the Lower Traverse beds of Northern Michigan.

Stropheodonta fissciosta Winchell.

This species is another typical Traverse form in which formation it abounds. A single specimen has been obtained from the Dundee of the Sibley quarry. It is readily recognized by its divided costae, otherwise resembling the preceding. A closely related species is figured by Kindle from the Jeffersonville of the Falls of the Ohio, as *S. plicata* Hall.

Stropheodonta demissa (Conrad).

This characteristic Hamilton species is represented by a considerable number of specimens which show the typical form and bundled striae. They occur in coarse calcarenyte scattered through the section. A variety somewhat less convex than the normal form, and with a shorter hinge line with more rounded ends also occurs

in the lower beds. On the whole, the specimens resemble more closely those found in the lower shales of the Traverse beds to the north, than the coarser striated New York form.

The species is recorded from the Onondaga of New York, but the individuals are small and not typical. Those from the Dundee and the Columbus resemble more the Hamilton type than the variety from the Onondaga. The species is widely distributed in the Hamilton of North America.

Stropheodonta alpenensis sp. nov.

This species is the most abundant of any in the Traverse Group of Michigan, occurring throughout, with several modifications. It is about half the size of *S. demissa,* and looks not unlike a dwarfed representation of that species. Its uniform size, together with its ornamentation, however, show it to be distinct.

The species is not uncommon in the Dundee of Michigan, the specimens from this horizon agreeing in all respects with those from the Traverse Group. They often become very robust, and this is also true of the Traverse species. In such cases, the muscular impressions become strongly marked. This species probably occurs in the Columbus limestone of Ohio, as well as in the Dundee of Western Ontario.

Stropheodonta (Leptostrophia) perplana (Conrad).

This species is not uncommon in the Dundee of Southern Michigan, and the Columbus of Ohio. It is readily recognized by its flat character and the fine radiating striae. Not infrequently, concentric undulations, recalling the characters of *Leptaena rhomboidalis* occur, especially on the younger individuals.

The species is rather generally distributed through the formations. Its range elsewhere is from the Schoharie to the Chemung.

Stropheodonta (Pholidostrophia) iowaënsis (Owen).
(*Stropheodonta nacrea* Hall).

This characteristic Hamilton species is abundantly represented in the Dundee of Southern Michigan and the Columbus of Ohio. The limestone specimens rarely show the nacreous lustre observed in the specimens of the shales, but the characteristic form and absence of striae permit ready identification. Though reported from the Onondaga, it is most typical of the Hamilton in all the exposures of the latter from New York to Iowa. It occurs in the Sellersburg and Jeffersonville of Indiana.

Stropheodonta pattersoni Hall.

This Onondaga species is reported from the Columbus limestone of Ohio. Its convexity, extended hinge line with deflected angles, and distant striae alternating with finer ones, characterize the species. Some of the other limestone species might be mistaken for this, and there is some possibility that the identification is not absolute. In any case, it has not been found in the material from Michigan.

Genus STROPHONELLA Hall.

Strophonella ampla Hall.

This large, reversed form, with the pedicle valve convex in the young, but strongly concave in the adult, has been found in the Columbus limestone of Ohio, but has not yet been reported from Southern Michigan. It is a characteristic Onondaga species in New York and Ontario.

Genus LEPTAENA Dalman.

Leptaena rhomboidalis (Wilckins).

This widespread species is represented so far by a single specimen in the Dundee of Michigan, but appears to be more abundant in the Columbus limestone of Ohio. Its concentric wrinkles and sudden rectangular anterior deflections are sufficiently distinctive features. Its great range (Trenton to Waverly) makes it of little value as a horizon marker.

Genus SCHUCHERTELLA Girty.

(ORTHOTHETES of most authors.)

Schuchertella arctostriata Hall.

This species, with its irregular form, long hinge line, and alternating striae, seems to be well represented in the Dundee of Southern Michigan, where it occurs at several horizons. It has not been reported from Ohio, but is common in the Hamilton of New York, Ontario, and occurs in the Jeffersonville of Indiana, etc.

Schuchertella pandora Billings.

This Onondaga species occurs in the Columbus limestone of Ohio, and may also be represented in the Dundee of Michigan. Its

regular form, fine, sharp striae, strong curvature, and straight beak distinguish it. It is characteristic of the Onondaga of New York, Ontario, and elsewhere, and has been reported from the Devonic of Nevada.

Schuchertella (*Orthothetes*) *flabellum* Whitfield.

This small, strongly plicate species was described from the Columbus limestone of Ohio. It is unlike any other known Devonic form, but one from the Upper Monroe of Michigan agrees quite closely with this. Since Monroe species have before been described as Onondaga types, the horizon of this species should be verified. It occurs in the Sibley quarry, and also in the upper 100 feet of the Detroit shaft.

Genus CHONETES. Fischer de Waldheim.

Chonetes mucronatus Hall.

This is the most abundant and characteristic species of Chonetes in the Dundee of Southern Michigan. It is of medium size, with deflected cardinal angles, and with finer striae than is usual for this species in the Onondaga limestone of New York, etc. In this respect, the species agrees entirely with the specimens from the Marcellus shale of New York, the number of striae approximating 24-26. The spines are long, slender, and parallel to the hinge line. Altogether, the mutation of this species here presented agrees so closely with the Marcellus types as to lead to the supposition that they were contemporaneous, and that the species was *eurylithic*, or capable of occupying a wide range of bottom facies, i.e., from calcareous sand and mud to highly carbonaceous muds unsuited to most forms of organisms. The range of this species as a whole is rather wide, beginning in the Oriskany and continuing into the Hamilton. The various mutations, however, seem to be restricted to narrow stratigraphic zones.

In the Dundee of Southern Michigan, it is most abundant in the chert beds A and H (6 ft. and 2 ft. beds), and the chert bed over the 9 ft. bed. It is also found in the limestones at various levels in the Sibley quarry and in the upper layers penetrated by the salt shaft at Oakville, Detroit. It is also found in the Columbus of Ohio, and in the same rock in the region about Windsor, Ont. It occurs in the Sellersburg and Jeffersonville of Indiana, etc.

Chonetes gibbosa Hall.

This species is represented by a single specimen obtained from the lower beds of the Sibley quarry. It is very convex, with more numerous striae than in *C. mucronatus,* and with strong spines bent outward. The species elsewhere occurs in the Hamilton.

Chonetes deflecta Hall.

This species, with the convexity and general characters of *C. mucronatus,* but with much finer striae, more strongly deflected cardinal extremities, and rather more oblique spines, also occurs in the limestones of the Sibley quarry, and in the Columbus limestone of Northern Ohio. It is essentially a Hamilton species.

Other species recorded from the Columbus limestone of Ohio are: *C. acutiradiata* Hall, *C. arcuata* Hall, and *C. yandellana* Hall. Elsewhere these species are distributed as follows: *C. acutiradiata* from the Onondaga of New York, and the Jeffersonville of the Falls of Ohio, *C. arcuata* from the Onondaga of New York and *C. yandellana* from the Jeffersonville of the Falls of Ohio.

Genus STROPHALOSIA King.

Strophalosia truncata Hall.

This characteristic Marcellus species seems to be common in certain of the beds in the Dundee of Southern Michigan, especially the chert beds. The pedicle valve is convex, with a strong umbonal truncation, and with spinous ridges running for some distance and ending in spines of moderate length. The range of this species is from the Marcellus to the Portage, but it has not been reported from any lower horizon. It has so far remained unrecorded from the Columbus limestone of Ohio.

Genus PRODUCTELLA Hall.

Productella spinulicosta Hall.

This species is not uncommon in the limestones, where it is strongly convex, with rather strong spinous ridges and long spines. Some of the specimens have the character of *P. shumardiana* of the Onondaga limestone, these occurring in the upper beds of the Sibley quarry. The typical forms occur in the 2 ft. chert bed (Bed H) and in the chert bed above the 9 ft. bed. It is also found in other non-cherty beds of the quarry. Elsewhere it is most characteristic

of the Hamilton beds, though it has been recorded from the Onondaga.

Genus RHIPIDOMELLA Oehlert.

Rhipidomella variabilis sp. nov.

This is the commonest species of the Dundee limestone. It is transverse, varying in proportional height and width, approaching on the one hand *R. vanuxemi,* and on the other *R. penelope.* The pedicle valve varies from convex to nearly flat, while the brachial valve is strongly arched. Generally a well-marked, broad, but ill-defined sinus occurs toward the front of the pedicle valve, and a flattening, rarely a depression, in the brachial valve. The muscular impressions are like those of *R. vanuxemi.*

This species seems to have been the stock from which *R. vanuxemi, R. penelope,* and *R. livia* were derived, the various mutations leaning towards one or another. Some specimens are scarcely distinguishable from *R. penelope,* except that they do not reach the size of that species.

The young of typical *R. vanuxemi* is proportionately broader than the adult, a feature characteristic of the adult of *R. variabilis,* which, therefore, fulfills the requirements of an ancestral form in this respect.

The common form of this species is distinguished by its breadth and its median pedicle sinus. Some of the specimens approach *Schizophoria propinqua* in outline, but the hinge is always shorter and the muscular impressions are distinctive. The species is pretty generally present in the various beds of the Sibley quarry. It also occurs in other exposures of this formation in Southern Michigan and the adjoining Canadian region. It is found also in the Columbus limestone of Ohio.

Rhipidomella vanuxemi Hall.

This characteristic Hamilton species appears to be represented by a number of individuals from the Dundee of Southern Michigan. In this horizon, it has more the value of a fluctuating variety, but becomes well fixed in the succeeding Hamilton. It has been reported from the Onondaga, but its chief development is in the Hamilton of New York, etc. The species is also reported from the Columbus limestone of Northern Ohio.

Rhipidomella penelope Hall.

Several of the mutations of *R. variabilis* are sufficiently modified and increased in size so that they may virtually be regarded as *R. penelope*. The distribution seems general. Elsewhere this species is known only from the Hamilton.

R. livia Billings.

This species has been reported from the Columbus limestone of Ohio, and appears to be likewise represented from the Dundee of Southern Michigan. It occurs elsewhere in the Onondaga, as in Ontario. It is doubtfully reported from the Sellersburg of Indiana.

Genus SCHIZOPHORIA King.

Schizophoria iowaensis Hall.

This form is not uncommon in the Dundee limestone. It is large, robust, and very convex in the brachial valve, which bears a well marked median depression towards the front. The muscular impressions are small and deep. The species, on the whole, agrees most closely with the commoner forms of the Traverse Group, though some approach *S. propinqua* Hall. It is also found in the Columbus limestone and in the Onondaga of New York, etc. This species is especially abundant in Bed I (9 ft. bed) and in the beds above the lower 20 ft. of the Sibley quarry.

Genus PENTAMERELLA Hall.

Pentamerella arata Conrad.

This species has been recorded from the Columbus of Ohio, but the specimens are not typical, as are those of the Schoharie and Onondaga of New York. It is not definitely known from the Dundee of Michigan, though a fragmental specimen suggests its possible presence.

Pentamerella cf. pavilionensis Hall.

This species seems to be represented by a brachial valve having the characteristic form and plication. It was obtained above the 9 ft. bed. The species is a widely distributed Hamilton form.

Genus CAMAROTOECHIA Hall and Clarke.

This genus is represented by several species not fully identified. In the Columbus limestone occur *C. dotis* Hall, *C. billingsi* Hall, *C. carolina* Hall, and *C. thetis* Billings. The first of these is a Marcellus and Hamilton form; of the others *C. billingsi* occurs in the Onondaga of New York and Canada, *C. carolina* at the Falls of the Ohio, and *C. thetis* in the Onondaga of New York, the Sellersburg and the Jeffersonville of the Falls of the Ohio and the Devonic of Nevada.

Genus TROPIDOLEPTUS Hall.

Tropidoleptus carinatus Conrad.

This characteristic and diagnostic Hamilton species of Eastern North America has been reported from the Columbus limestone of Ohio. It has not been noticed in the Dundee, but it may prove to be present. If correctly identified, it furnishes a further link in the relationship of these strata to those of New York; for this species has, in North America, been found only in the Marcellus and Hamilton, though also occurring higher up.

Genus ATRYPA Dalman.

Atrypa reticularis Linnaeus.

This species is abundantly represented by normal individuals. It is also common in the mutation *elegans,* mut. nov., which is always small, but becomes very robust, often approaching a globular form. The muscular impressions are strongly marked, and the surface feature comprise fine, uniform striae, repeatedly bifurcating and crossed by very distant, strong, concentric lines, which produce a slight nodosity at the crossing. Repeated bifurcation of the striae keeps them fine and greatly increases their number.

The pedicle valve is rather more strongly convex than in the normal form, and in outline it is often somewhat elongate. Sometimes there is a faint flattening down the middle of the brachial valve, giving this form some resemblance to *A. impressa* of the Schoharie.

The species occurs in the chert bed and in the limestones of the quarry. It has also been reported from the Columbus limestone of Ohio.

Atrypa spinosa Hall.

This species is abundantly represented, being more numerous than the preceding. It has moderately coarse plications, which, in some cases, are seen to continue as tubular spines beyond the edge of the shell. In some forms, the plications are few and coarse, with strong concentric lines, as in the typical Hamilton specimens. The number of primary plications is not over 8 or 10, and they increase by repeated division. This species ranges pretty nearly throughout the limestone. It has not been recorded from the Columbus of Ohio, and elsewhere it is chiefly confined to the Hamilton, though it is said to range up into the Chemung. It occurs in the Sellersburg of the Falls of the Ohio and Charlestown, Ind.

Genus CYRTINA Davidson.

Cyrtina hamiltonensis Hall.

This characteristic Hamilton species is also represented in the Dundee of Southern Michigan and the Columbus limestone of Ohio. It is typical, with moderately curved hinge area, and occurs in beds I and J of the Sibley quarry, as well as in the upper 100 feet penetrated by the Detroit salt shaft. The variety *recta,* with straight hinge area, is also represented. Though reported to range from the Onondaga to the Portage, this species is most typically represented in the Hamilton, where it is a diagnostic fossil. Both occur in the Sellersburg and Jeffersonville of the Falls of the Ohio.

Genus SPIRIFER Sowerby.

Spirifer bidorsalis Winchell.

This is a small species characteristic of some of the lower beds of the Traverse Group of the Traverse Bay region. It is elongate, with a moderate hinge area, rounded, strong plications, about 9 on each side of the sinus, and a low plication in the sinus. The fold is divided by a sharp median groove. In the specimens from the Traverse shales, strong concentric striations occur, but, in the specimens from the limestone, these are seldom visible. The species is scattered through the upper layers in the Sibley quarry. A variety occurs which is larger proportionally, and more robust, and has fewer plications. This variety is found also in the Columbus of Ohio.

Spirifer gregarius Clapp.

This species seems to be represented by several small individuals with rather weak plications. They are strongly convex and have a profound median sinus and strongly overarching beak of the pedicle valve. They are smaller than the normal forms from the Onondaga of New York and the Sellersburg and Jeffersonville of the Falls of the Ohio, and seem to be confined to the upper beds in the quarry. The form occurs in the Columbus limestone.

Spirifer grieri Hall.

This species is readily recognized by the plications on the fold and sinus. It is represented by a number of individuals, the distribution of which through the beds of the Sibley quarry and the upper part of the Detroit salt shaft show it to be a rather common form. It is also found in the Columbus limestone and in the Onondaga of New York and the Jeffersonville of the Falls of the Ohio.

Spirifer manni Hall.

This species, originally described from the Columbus limestone of Ohio, is common in the Dundee of Southern Michigan. It is generally elongate, with moderate area, and a marked flattening or median depression on the fold of the brachial valve. Genetically it appears to be closely related to *S. johnsoni* Grabau Mss. of the Lower Traverse, the only difference being in the faint lateral plications in the sinus of *S. johnsoni.* Through the last named species, this species is related to *S. oweni,* which is approached by some accelerated individuals of *S. manni* in form, but the plications of the sinus are scarcely developed. Once in a while, the faint plications are formed, so that the specimens may be referred either to *S. johnsoni* or to *S. oweni.* This is the common Spirifer of the Dundee, occurring more or less abundantly throughout the series.

S. manni occurs in the Columbus limestone, and in the Onondaga of Western New York and the Jeffersonville of the Falls of the Ohio.

Spirifer oweni Hall.

Some of the Dundee specimens of Spirifer approach *S. oweni* so closely that they may be regarded as representing that species. These are the accelerated derivatives of *S. manni.* They have been found in the upper beds. Elsewhere the species occurs in the Hamilton (Sellersburg), of the Falls of the Ohio and the Lower

Traverse of Michigan. Other species of Spirifer recorded from the Columbus of Ohio are: *S. acuminatus* Conrad, *S. duodenarius* Hall, *S. euryteines* Owen, *S. fimbriatus* Conrad, *S. macra* Hall, *S. machrothyris* Hall, *S. segmentus* Hall, *S. varicosa* Hall, and *S. raricostus* Conrad.

OTHER GENERA.

The genus MERISTELLA Hall is represented in the Columbus limestone by two species, *M. nasuta* Conrad and *M. scitula* Hall. An unidentified fragment of a species of this genus occurs in the Dundee of Michigan. The genus NUCLEOSPIRA Hall is represented by *N. concinna* Hall in the Columbus limestone, and the genus EUNELLA by *E. sullivanti* (Hall). Finally, the genus RFEMERELLA is represented by *R. grandis* Vanuxem, a characteristic Hamilton form, found in New York, Indiana and Kentucky; and the genus CRANIA by *C. crenistriata* Hall and *C. (Creniella) hamiltoniae* Hall, both Hamilton species, though the former also occurs in the Onondaga of New York, and the latter in the Jeffersonville of the Falls of Ohio.

The following table shows the range of the species in the Dundee and Columbus limestones:

TABLE LXVI.—SUMMARY OF THE BRACHIOPOD FAUNA.

	Dundee.	Columbus.	Typical Onondaga.	Typical Marcellus and Hamilton.
1. *Stropheodonta inaequiradiata*	X	X	X	
2. *S. dundeensis*	X			
3. *S. hemispherica*	X	X	X	
4. *S. concava*	X		X	X
5. *S. costata (solidicosta)*	X			X
6. *S. finicosta*	X			X
7. *S. demissa*	X	X	?	X
8. *S. alpenensis*	X	?		X
9. *S. perplana*	X	X	X	X
10. *S. (Pholidostrophia) iowaensis*	X	X	X	X
11. *S. pattersoni*		X	X	
12. *Strophonella ampla*		X	X	
13. *Leptaena rhomboidalis*	X	X	X	X
14. *Schuchertella arctostriata*	X			X
15. *S. pandora*		X	X	
16. *S. flabellum*		X		
17. *Chonetes mucronatus*	X	X	X	X
18. *C. gibbosus*	X			X
19. *C. deflectus (C. vicinus)*	X	X		X
20. *C. acutiradiata*		X	X	
21. *C. arcuata*		X	X	
22. *C. yandellanus*		X	X	
23. *Strophalosia truncata*	X			X
24. *Productella spinulicosta*	X	X	X	X
25. *Rhipidomella variabilis*	X			
26. *R. vanuxemi*	X	X	X	X
27. *R. penelope*	X			X
28. *R. livia*	X	X	X	
29. *Schizophoria iowaensis*	X	?		X
30. *S. propinqua*	X	X	X	
31. *Pentamerella arata*	?	X	X	
32. *P. cf pavilionensis*	X			X
33. *Camarotoechia dotis*		X		X
34. *C. billingsi*		X	X	
35. *C. carolina*		X	X	
36. *C. thetis*		X	X	X
37. *Tropidoleptus carinatus*		X		X
38. *Atrypa reticularis*	X	X	X	X
39. *A. spinosa*	X		X	X
40. *Cyrtina hamiltonensis*	X	X	X	X
41. *C. hamiltonensis var. recta*	X			X
42. *Spirifer bidorsalis*	X			X
43. *S. gregarius*	X	X	X	X
44. *S. grieri*	X	X	X	
45. *S. manni*	X	X	X	
46. *S. oweni*	X	X		X
47. *S. acuminatus*		X	X	X
48. *S. duodenarius*		X	X	X
49. *S. euryteines*		X		X
50. *S. (Reticularia) fimbriatus*		X	X	X
51. *S. macrus*		X	X	
52. *S. macrothyris*		X	X	
53. *S. segmentus*		X	?	
54. *S. varicosus*		X	X	X
55. *S. raricostus*		?	X	
56. *Meristella nasuta*		X	X	
57. *M. scitula*		X		
58. *Nucleospira concinna*		X		X
59. *Eunella sullivanti*		X	X	
60. *Roemerella grandis*		X		X
61. *Crania cranistriata*		X	X	X
62. *Craniella hamiltoniae*		X		X

From the foregoing table it will be seen that the Hamilton species predominate. Of the 62 species recorded, 24, or 38 per cent., are unknown outside of the Onondaga elsewhere, while 28, or 45 per

cent., are either restricted to or most characteristic of the Hamilton group. Moreover, such very typical New York Hamilton or Marcellus fossils as *Stropheodonta demissa, S. iowaensis, Schuchertella arctostriata, Chonetes mucronatus, Strophalosia truncata, Productella spinulicosta, Rhipidomella vanuxemi, R. penelope, Camarotoechia dotis, Tropidoleptus carinatus, Cyrtina hamiltonensis, C. recta, Reticularia fimbriata, Nucleospira concinna, Roemerella grandis,* and *Craniella hamiltoniae* strongly suggest Hamilton affinities. Such is also the case with the species identical with those of the Traverse fauna of Michigan, as *Spirifer bidorsalis, S. euryteines, S. oweni, Stropheodonta alpenensis, S. plicata,* and *S. fissicosta.* The abundance of Onondaga types shows that the fauna is not true Hamilton, but rather a transitional fauna.

Class VII. PELECYPODA Goldfuss.

(LAMELLIBRANCHIATA de Blainville).

Genus SANGUINOLITES McCoy.

Sanguinolites sanduskyensis Meek.

This species, occurring in the Columbus limestone in Northern Ohio, appears to be represented in the Dundee by a large specimen, an internal mold about 55 mm. high. So far as can be ascertained from the fragmentary character, it can be referred to this species.

Genus PTERINEA Goldfuss.

Pterinea flabellum (Conrad)?

This species is doubtfully identified from the Columbus limestone, the specimens being large, coarse forms, very unlike the Hamilton types.

Genus ACTINODESMA Sandburger.

(GLYPTODESMA HALL).

Actinodesma erectum Conrad.

This large and coarse species is represented by several left valves in the Dundee of Michigan. It is characterized by an extended hinge line, slightly defined wing, ending in an acute point, and by coarse concentric growth striae and undulations. The species occurs in the coarser rock of the upper beds (Bed I) and 12 ft.

above the lower 20 ft. in the Sibley quarry. Elsewhere, it is a typical Hamilton form though occurring in the Jeffersonville of the Falls of Ohio. A closely related species, *A. subrectum* Whitfield, occurs in the Delaware limestone of Ohio.

Genus PLETHOMYTILUS Hall.

Plethomytilus ponderosus Hall.

This large species is represented in the Columbus of Ohio and the Onondaga of New York and Ontario. It has not been noted as yet in the Dundee.

Genus MYTILARCA Hall.

Mytilarca percarinata Whitfield.

This species is known only from the Columbus limestone of Dublin, Ohio.

Genus CONOCARDIUM Bronn.

Conocardium trigonale Hall.

This is a well represented species abounding in some of the layers of the Dundee in Southern Michigan. It occurs both as shells and internal molds. It is equally common in the Columbus of Ohio and occurs at the Falls of the Ohio. It is found in the Schoharie and Onondaga of New York. A closely related form occurs in the Traverse beds of Michigan.

Conocardium ohioense Meek.

This small species with sharply separated, produced posterior extremity, occurs in the Columbus limestone of Ohio, and the Jeffersonville (?) of the Falls of the Ohio. It has not yet been reported from Michigan.

Genus ACTINOPTERIA Hall.

Actinopteria decussata Hall.

This large and characteristic Hamilton species is represented by specimens on the average somewhat smaller than those found in the Hamilton beds. They have the characteristic form and obliquity, but generally lack the pronounced radii owing to the exfoliation of the shell. They are more or less scattered through the Dundee of the Sibley quarry, having been found in the 12 ft. bed above the lower 20 ft.; in Bed D (5 ft. bed); in Bed I (9 ft.

bed); and in the beds above this. The species elsewhere is known only from the Hamilton beds.

A small specimen with strong concentric wrinkles decussating the striae, has been obtained from the 9 ft. bed. The striae are round and thicker than is general in the Hamilton specimens, but the form and obliquity are normal. The end of the wing projects slightly beyond the shell below.

Genus AVICULOPECTEN McCoy.

Aviculopecten similis (Whitfield).

This species, described by Whitfield from "the thin, shaly layers of bituminous limestone from above the 'bone bed' at Smith and Price's quarry near Columbus, Ohio," and referred to the Marcellus, is represented by a single left valve agreeing in all respects, including size, with the type. Its alternating striae and extreme convexity and small size are characteristic features.

Whitfield compares this with *Actinopteria decussata*, but the comparison is not apt. That species is more oblique and more elongate and the striae are interrupted. The hinge is unknown, but in form the species resembles an Aviculopecten. It is not improbable, however, that this is the young of *Aviculopecten sanduskyensis.*

Aviculopecten sanduskyensis Meek.

This species is described from the Columbus of Ohio, but has not been obtained from Michigan.

Aviculopecten crassicostatus Hall and Whitfield.

This occurs likewise in the Columbus limestone, but is still unrecorded from the Michigan Dundee. It was originally described from the Sellersburg of the Falls of the Ohio.

Aviculopecten sp.

A form with distant striae and strong concentric undulations has been obtained from the Sibley quarry above the 9 ft. bed. It is too poorly preserved for specific determination.

Genus MODIOMORPHA Hall.

Modiomorpha elliptica?

Recorded doubtfully from the Columbus limestone of Ohio.

Modiomorpha perovata (Meek and Worthen).

This species, described from Ohio, has so far not been found in Michigan, though there are indications that it may occur there.

Genus GONIOPHORA Phillips.

Goniophora perangulata Hall.

This acutely angular species, characteristic of the Schoharie beds of New York, has also been reported from the Columbus limestone of Ohio, but is still unknown in Michigan.

Genus PARACYCLAS Hall.

Paracyclas elliptica Hall.

This large species, with irregular and lamellose concentric striae, is abundantly represented in the Dundee of Southern Michigan and the Columbus of Ohio. The specimens are mostly compressed or distorted and are generally over an inch in diameter (1½ to 1¾ in. is more nearly the average). When perfect, they approach a circular form, while the depth or transverse diameter is one-half the vertical or over. Some specimens suggest in their striae an approach to *P. lirata* of the Hamilton Group. The species occurs in the Onondaga of New York, but is more abundant in the Mackinac limestone of Northern Michigan. It occurs more rarely in the Hamilton of New York. In the Falls of the Ohio region, it occurs in the Jeffersonville and Sellersburg.

The Dundee specimens are distributed more or less throughout the series exposed in the Sibley quarry. The species also occurs in the adjoining region of Ontario.

Paracyclas ohioensis Meek.

This small species, described from the Columbus limestone of Ohio, has also been obtained from the Sellersburg limestone of the Falls of the Ohio region. It has not been definitely identified from Michigan.

Summary of the Pelecypod Fauna. The pelecypod fauna of the Dundee and Columbus is more individualized than the brachiopod fauna, having proportionally more species peculiar to it. Nevertheless, there are a number of distinct Hamilton species present, such as *Actinodesma erectum* (Conrad), *Actinopteria decussata* Hall, and the small *Aviculopecten similis* Whitfield, described from the "Marcellus" of Ohio and *Paracyclas ohioense* from the Sellers-

burg of Indiana. Against these must be placed the number of distinctive Onondaga and Schoharie species, as *Plethomytilus ponderosus* Hall, *Conocardium trigonale, Goniophora perangulata* Phill., and *Paracyclas elliptica* Hall. On the whole, it seems as if the fauna inclines more to the Onondaga-Schoharie type than to the Hamilton type, since the most abundantly represented species belong to the former.

Class VIII. SCAPHOPODA Browne.

Genus DENTALIUM Linnæus.

Dentalium (*Lacvidentalium*) *Martini* Whitfield.

This smooth, rapidly enlarging and moderately curved species is the earliest known from American rocks. It has been described from the Columbus limestone of Ohio, and not yet noted elsewhere.

Class IX GASTROPODA.

The gastropods as a whole are poorly preserved in the Dundee limestone of Michigan, occurring mostly as internal molds with the shell removed. As a result, identification of species is difficult, especially if, as is generally the case, compression has distorted the mold. The following determinations are subject to revision if better material is obtained.

Genus PLEUROTOMARIA.

Pleurotomaria (*Pleurorima*) *lucina* Hall.

This large species seems to be well represented by internal molds, which are commonly compressed, so that the spire appears lower than normal. The "band," when visible, seems to be near the middle of the whorl and vertical. Some of the compressed forms resemble *P.* (*Spiroraphe*) *arata,* but the superior-placed "band" of that species has not been observed. No surface markings are shown. The specimens are most abundant in Bed A (the 6 ft. bed) of the Sibley quarry, but occur also higher up (top beds and Bed G). They have also been collected from the Dundee of the salt shaft between 83 and 105 ft. from the top. *P. lucina* has been obtained also from the Columbus limestone of Ohio, and is characteristic of the Hamilton of New York; but it is reported likewise from the Onondaga of that state. It occurs in the Sellersburg

beds (?) and the Jeffersonville limestone of the Falls of the Ohio, etc.

Pleurotomaria (*Euryzone?*) *hebe* Hall.

This species, found in the Columbus of Ohio, is represented in the Dundee of Southern Michigan by two internal molds. These show only the form and apical angle of the species, the ornamentation being lost. The specimens are one from Bed A (6 ft. bed), and the other from the beds above the 9 ft. bed in the Sibley quarry. Elsewhere this species is found in the Onondaga of Western New York.

Pleurotomaria (*Lophospira*) *adjutor* Hall.

This ornamented species has been found in the Columbus limestone of Ohio and the Onondaga of New York, but has not been observed in the Dundee of Michigan.

Genus HORMOTOMA Salter.

Hormotoma (*Hormotomina*) *maia* (Hall).

This slender turreted species with rounded whorls is represented by fragments of internal molds in the Dundee of Southern Michigan (Bed I or 9 ft. bed). The characteristic duplicate character of the band is not well shown, though in one case the central carina is indicated. It was originally described from the Columbus limestone of Ohio, and has not been found elsewhere.

Hormotoma desiderata Hall.

This species, associated with the preceding in the Columbus limestone of Ohio, and distinguished from it by its greater apical angle, flatter shoulder of whorls, and simple band, has been doubtfully reported from the Onondaga of New York, but is still unknown from other localities. It probably occurs in the Dundee of Michigan; a mold approaching it has been obtained from the upper beds of the Sibley quarry. It has also been recorded from the Jeffersonville of Indiana.

Genus COELIDIUM Clarke and Ruedemann.

This genus seems to be represented by the internal mold of an unidentified species. The obliquity of the whorls is very slight, and there is a hollow axis from loose coiling. The whorls are round and the band is just below the periphery. It was obtained from the Dundee of the Sibley quarry; exact level not noted.

Genus EUOMPHALUS Sowerby.

Euomphalus (*Pleuronotus*) *decewi* Billings.

This species is most characteristically developed in the Columbus limestone of Ohio, but has also been obtained from the Onondaga of New York and Canada from the Jeffersonville of the Falls of the Ohio, etc., and from the Mackinac limestone of Northern Michigan. Its rapidly enlarging whorls, flat or sunken spire, and sharp keel readily distinguish it. In the collections of Dundee forms, it is represented by two young specimens showing depressed spire, a flat periphery, and rather rounded angles. Found in the upper beds.

Genus TROCHONEMA Salter.

Trochonema meekanum S. A. Miller (*T. tricarinatum* Meek).

This species, found in the Columbus limestone of Ohio, is represented by a single crushed specimen in the collections of Dundee material from Southern Michigan, recognizable from its carinated shoulder angle. From Bed I (9 ft. bed) of the Sibley quarry. It has also been found in the Jeffersonville limestone of Indiana.

Genus PLATYCERAS Conrad.

Platyceras dumosum Conrad.

A spiny species, represented by a number of individuals in the Dundee limestone, having considerable variation in form and spinosity. Spines generally represented by irregular nodes; the shell as a whole expanding rapidly. The apex is always strongly enrolled. Obtained from the lower beds, A (9 ft. bed) and D (5 ft. bed), and elsewhere in the Sibley quarry. It is found in the Columbus limestone of Ohio, in the Onondaga of New York and Ontario, and in the Sellersburg limestone of the Falls of the Ohio.

Platyceras attenuatum Meek.

This species, originally described from the Columbus limestone of Ohio, also occurs in the Dundee of Michigan. It is slender and narrow, with slight enlargements and rough nodes. It occurs some distance above the bottom of the beds (above the lower 20 ft.) in the Sibley quarry. The species has also been recorded from the Sellersburg bed of Charlestown, Ind.

Platyceras carinatum Hall.

This species, characterized by a sharp, carinated periphery, is represented in the Columbus limestone of Ohio, and by a small specimen in the Dundee of Southern Michigan. It occurs in the Hamilton of New York and the Sellersburg and Jeffersonville limestones of Indiana. Other species of Platyceras found in the Columbus limestone of Ohio, and probably also occurring in the Dundee of Michigan, are: *P. bucculentum* Hall, found besides in the Hamilton of New York and the Sellersburg and Jeffersonville limestones of Indiana; *P. (Igoceras) conicum* Hall, found also in the Hamilton of New York (also Onondaga?), and at the Falls of the Ohio (Jeffersonville and Sellersburg); *P. multispinosum* Meek also found in the Jeffersonville at the Falls of the Ohio; and *P. (Palaeocapulus?) squalodens* Whitfield.

Genus CALLONEMA Hall.

Callonema bellatulum Hall.

(*Isonema bellatulum* Hall).

This species, described from the Columbus limestone of Ohio, and occurring also in the Jeffersonville limestone of the Falls of the Ohio, is represented by a single internal mold from the Dundee of the upper five feet of the lower 20 ft. of the limestone of the Sibley quarry. The form of the whorls and the apical angle correspond exactly with those of the type specimen from Ohio, but no trace of the ornamentation is retained.

Besides the species already noted, the following have been recorded from the Columbus limestone of Northern Ohio.

TABLE LXVII.

		Range elsewhere.
1.	*Collonema lichas* Hall.	Onondaga of Western New York, Jeffersonville of Ind.
2.	*Callonema humile* Meek.	Sellersburg of Falls of the Ohio.
3.	*Palaeotrochus kearneyi* Hall.	
4.	*Turbinopsis shumardi* (Vern).	Jeffersonville of Falls of Ohio and New York?
5.	*Isonema depressum* M. and W.	Hamilton of Illinois.
6.	*Xenophora antiqua* Meek.	
7.	*Naticopsis aequistriatus* Meek.	
8.	*N. cretacea* H. and W.	
9.	*N. laevis* Meek.	Jeffersonville (?) of Falls of Ohio.
10.	*Loxonema leda* Hall.	
11.	*L. hamiltoniae* Hall.	Hamilton of New York, Sellersburg of Ind.
12.	*L. parvulum* Whitfield.	
13.	*L. pexatum* Hall.	Onondaga of New York.
14.	*Macrocheilus priscus* Whitfield.	
15.	*Cyclonema* (?) *doris* Hall.	Schoharie of New York.
16.	*Hormotoma* (?) *obsoleta* Meek.	
17.	*Bellerophon newberryi* Meek.	
18.	*B. propinquus* Meek.	
19.	*B. pelops* Hall.	Schoharie and Onondaga of New York, Jeffersonville of Indiana.

Summary of the Gastropod Fauna of the Dundee and Columbus Limestones.

While the majority of species are so far known only from these limestones, and are therefore of no immediate significance in correlation, a large number are elsewhere represented. Out of a total of about 15 species found in other localities, the division between the Hamilton and Onondaga is nearly equal. Most of the seven or eight Hamilton species are typical of that horizon, showing that the gastropod fauna must be considered intermediate. Probably many of the distinctive species will be found in the Traverse fauna of Northern Michigan, when the study of the latter is completed.

Platyceras carinatum Hall.

This species, characterized by a sharp, carinated periphery, is represented in the Columbus limestone of Ohio, and by a small specimen in the Dundee of Southern Michigan. It occurs in the Hamilton of New York and the Sellersburg and Jeffersonville limestones of Indiana. Other species of Platyceras found in the Columbus limestone of Ohio, and probably also occurring in the Dundee of Michigan, are: *P. bucculentum* Hall, found besides in the Hamilton of New York and the Sellersburg and Jeffersonville limestones of Indiana; *P.* (*Igoceras*) *conicum* Hall, found also in the Hamilton of New York (also Onondaga?), and at the Falls of the Ohio (Jeffersonville and Sellersburg); *P. multispinosum* Meek also found in the Jeffersonville at the Falls of the Ohio; and *P.* (*Palaeocapulus?*) *squalodens* Whitfield.

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Callonema bellatulum Hall.

(*Isonema bellatulum* Hall).

This species, described from the Columbus limestone of Ohio, and occurring also in the Jeffersonville limestone of the Falls of the Ohio, is represented by a single internal mold from the Dundee of the upper five feet of the lower 20 ft. of the limestone of the Sibley quarry. The form of the whorls and the apical angle correspond exactly with those of the type specimen from Ohio, but no trace of the ornamentation is retained.

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4.	*Turbinopsis shumardi* (Vern).	Jeffersonville of Falls of Ohio and New York?
5.	*Isonema depressum* M. and W.	Hamilton of Illinois.
6.	*Xenophora antiqua* Meek.	
7.	*Naticopsis aequistriatus* Meek.	
8.	*N. cretacea* H. and W.	
9.	*N. laevis* Meek.	Jeffersonville (?) of Falls of Ohio.
10.	*Loxonema leda* Hall.	
11.	*L. hamiltoniae* Hall.	Hamilton of New York, Sellersburg of Ind.
12.	*L. parvulum* Whitfield.	
13.	*L. pexatum* Hall.	Onondaga of New York.
14.	*Macrocheilus priscus* Whitfield.	
15.	*Cyclonema* (?) *doris* Hall.	Schoharie of New York.
16.	*Hormotoma* (?) *obsoleta* Meek.	
17.	*Bellerophon newberryi* Meek.	
18.	*B. propinquus* Meek.	
19.	*B. pelops* Hall.	Schoharie and Onondaga of New York, Jeffersonville of Indiana.

Summary of the Gastropod Fauna of the Dundee and Columbus Limestones.

While the majority of species are so far known only from these limestones, and are therefore of no immediate significance in correlation, a large number are elsewhere represented. Out of a total of about 15 species found in other localities, the division between the Hamilton and Onondaga is nearly equal. Most of the seven or eight Hamilton species are typical of that horizon, showing that the gastropod fauna must be considered intermediate. Probably many of the distinctive species will be found in the Traverse fauna of Northern Michigan, when the study of the latter is completed.

Class X. CONULARIDA Miller and Gurley.

(*Pteropoda* of authors).

Genus TENTACULITES Schlotheim.

Tentaculites scalariformis Hall.

This is a common species of certain layers of the Dundee of Southern Michigan. It has been found at various levels in the Sibley quarry, including Bed G (6 ft. bed), H (2 ft. bed), J (6 ft. bed) and above the lower 20 ft. It occurs most abundantly in the Dundee of the salt shaft, at about 105 ft. below the surface. It is likewise common in the Columbus limestone of Ohio, and has been recorded from the Onondaga of New York and from the Sellersburg and Jeffersonville of Indiana.

Genus CONULARIA Miller.

Conularia elegantula Meek.

This has been described from the Columbus of Ohio, but has not been noted as yet from the Dundee of Michigan.

Class XI. CEPHALOPODA Cuvier.

Genus ORTHOCERAS Breynius.

Several species of Orthoceratites occur in the Dundee of Southern Michigan, but no specimens sufficiently well preserved for specific identification have so far been found. From the Columbus of Ohio have been recorded *O.* (*Spiroceras*) *nuntium* Hall, known also from the Hamilton of New York; *O. ohioense* Hall, and *O. profundum* Hall, also known from Onondaga of Western New York.

Genus TREMATOCERAS Whitfield.

Trematoceras ohioense Whitfield.

This species, described from the Columbus limestone of Ohio. probably also occurs in the Dundee of Michigan, as indicated by several imperfect specimens.

Genus GYROCERAS Meyer.

Gyroceras (*Ryticeras*) *cyclops* Hall.

This species occurs in the Columbus limestone of Ohio, including

the beds of Kelley's Island. It also occurs in the Onondaga of New York, but so far has not been recorded from Michigan.

Gyroceras (*Ryticeras*) *columbiense* Whitf.

This species, described from the Columbus of Ohio, has not been found elsewhere so far, but probably occurs in Michigan, since it is a common species.

Gyroceras (*Centroceras*) *ohioense* Meek.

This large species, described from the Columbus of Ohio, is also found in the Dundee of Michigan. In the specimens observed, the coiling is somewhat loosened toward the aperture, and the ornamentation of some individuals appears coarser than in the type. They occur in Bed I (9 ft. bed) and elsewhere.

Gyroceras (*Gigantoceras*) *inelegans* Meek.

This large species, originally described from the Columbus limestone of Ohio, also occurs in the Dundee of the Sibley quarry. A single large specimen has been obtained, with roundish smooth whorls enlarging rapidly. It has also been reported doubtfully from the Jeffersonville of the Falls of the Ohio.

Gyroceras seminodosus Whitf.

This appears to be a young form, possibly of *Discites inopinatus*. It has been found in the Columbus limestone of Ohio.

Genus NAUTILUS.

Nautilus (*Discites*) *ammonis* Hall.

A large nautilicone with deeply concave septa apparently belongs to this species. It was obtained from the Sibley quarry. It has not been recorded from Ohio, but has been found loose in Southern Michigan.

Nautilus (*Discites*) *inopinatus* Hall.

This nautilicone, characterized by sparse oblique nodes, on the ventrol-lateral angles, and smaller nodes on the umbilical margin, is represented by a single specimen from the Dundee of the Sibley quarry. It is quadrangular in section, but does not preserve the shell. The species has been found in the Columbus limestone of Sandusky, Ohio.

Genus POTERIOCERAS McCoy.

Poterioceras amphora (Whitf).

This species, described from the Columbus limestone of Ohio, also occurs in the Dundee of Michigan. Specimens were found in Bed B (7 ft. bed) of the Sibley quarry which correspond closely to the type specimen, having the aperture rather strongly contracted, the axis of the aperture being transverse to that of the rather strongly compressed shell. The species is unknown outside of these two formations, but closely similar, if not identical ones, occur in the Traverse group of Northern Michigan.

Poterioceras hyatti (Whitf).

This species was likewise described from the Columbus limestone of Ohio. It appears to be not uncommon in the Dundee of Southern Michigan. The curved form and aperture contracted below the top, where it again slightly expands, characterize the species. The axis of the aperture is parallel to the broad axis of the shell. This species has not yet been recorded from other horizons.

Poterioceras eximium (Hall).

This species has been recorded from the Columbus limestone of Ohio, but has not been found in Michigan. It was originally described from the Onondaga limestone of New York.

Poterioceras sciotense Whitf.

This species is at present known only from the Columbus limestone of Ohio.

Summary of the Cephalopod Fauna of the Dundee and Columbus limestone. The cephalopods more than any other class seem to be represented by peculiar species not yet found elsewhere. Of those known from other localities, however, only one (*Spiroceras nuntium*) is a typical Hamilton form, while three or four have previously been recorded from the Onondaga of New York or elsewhere. So far as the cephalopods seem to indicate, the fauna is less advanced than we should suppose from other classes of organisms.

Class XII. CRUSTACEA.

Order TRILOBITA.

Genus PROETUS Steininger.

Proetus conicus sp. nov.

This species is represented by a single cranidium. It is characterized by a conical glabella resembling that of *P. curvimarginatus* from the Schoharie of Pendleton, Ind., but has only three lateral furrows, the posterior one curving strongly backward to the occipital furrow, the middle curving slightly backward, while the upper scarcely curves at all. This species was figured and described by the author from the Hamilton shales of Eighteen-Mile Creek. It was provisionally and doubtfully referred to *P. curvimarginatus*. (Bull. Buffalo Soc. Nat. Sci., vol. VI., p. 316, fig. 261, 1898). *Proetus prouti* from the Hamilton of Iowa has a somewhat similar but less conical glabella. The specimen was obtained from Bed I (9 ft. bed).

Proetus crassimarginatus Hall.

This species, described from the Onondaga of New York and Ontario, is abundantly represented in the Dundee of Southern Michigan and the Columbus limestone of Ohio. It occurs mostly as pygidia, which are readily recognized by their strong convexity, the elevated, rounded axis, and strongly downcurving sides with rounded margins. The species ranges throughout the beds of the Sibley quarry and occurs in the other exposures of the Dundee and Columbus. It is known from the Jeffersonville and Sellersburg of Indiana and the Falls of the Ohio.

Proetus planimarginatus.

This species is readily distinguished from the preceding by its large flat pygidium with its gently convex axis, semi-elliptical outline, and pronounced margin. It occurs in the Columbus limestone of Ohio and is not uncommon in the Dundee of Southern Michigan.

Genus DALMANITES Emmrich.

Dalmanites (Chasmops) calypso Hall and Clarke.

This species is readily recognized by the angular, high and tuberculated axis of the pygidium with the pleurae grooved. The Michigan specimens resemble more nearly those figured by Kindle

from the Sellersburg beds of Ohio than those from the Onondaga of New York. (Compare Fig. 3, Pl. 30, Ind. Geol, Surv., 25th Ann. Rep't.; and Pal. N. Y. Vol. VII., Pl. XI. A, Fig. 19). In some specimens, the spines are less marked and the pleural grooves fainter. This is more like the type figured by Hall and Clarke. The species has also been recorded from the Columbus limestone of Sandusky, Ohio.

Dalmanites selenurus Green.

This species, known from the Onondaga limestone of New York, and the Jeffersonville of the Falls of Ohio, has been recorded from the Columbus of Ohio. It is thus far unknown in the Dundee of Michigan.

Dalmanites ohioensis Meek.

This species occurs in the Columbus limestone of Ohio.

Genus PHACOPS Emmrich.

Phacops rana Green.

This common Onondaga and Hamilton species occurs in the Columbus limestone of Ohio and is represented by pygidia in the Dundee of Southern Michigan.

Summary of Trilobite Fauna of the Dundee and Columbus Limestones.

So far as the Trilobites permit correlation, the Dundee-Columbus fauna must be considered an intermediate one between Onondaga and Hamilton, with a leaning toward the Hamilton side. Species of Hamilton affinity are: *Proëtus conicus* Grabau, *Chasmops calypso* Hall and Clarke var., and *Phacops rana* Green. Species of Onondaga affinities are: *Proëtus crassimarginatus* Hall and *Dalmanites selenurus* Green. The *Proëtus crassimarginatus* type seems to be a long lived one, for it is already represented in Southern Michigan in the Upper Monroe (Siluric). Against this may perhaps be offset, at least in part, the fact that both *Chasmops calypso* and *Phacops rana* occur elsewhere in the Onondaga as well as in the Hamilton.

VERTEBRATA.

Class I. PISCES.

Remains of Fishes are not uncommon in the Columbus limestone of Ohio and the Dundee of Michigan. A number of species have been described from the Columbus limestone. In the Dundee, so

far, have been recognized fragments of Onychodus, Machaeracanthus, and Rhynchodus.

GENERAL SUMMARY OF THE DUNDEE-COLUMBUS FAUNA OF SOUTHERN MICHIGAN AND NORTHERN OHIO.

The Protozoa and Stromatoporoids furnish at present little evidence for the age of the limestones, since the only recorded Protozoon (*Calcisphæra robusta* Williamson) is a long lived form continuing into the Carbonic, while the Stromatoporoids are not yet fully identified. The same is true of the Bryozoa, Scaphopoda, Conularida, and fish remains. The other classes, however, furnish more or less conclusive evidence regarding the age of this fauna as a whole. The corals and gastropods indicate an intermediate position for the fauna; the Brachiopods and Trilobites show a leaning to the Hamilton fauna; while the Pelecypoda and Cephalopoda incline to the Onondaga. In the Monroe formation, the Cephalopoda were found to be mostly of Lower Silurian (Niagaran) types, while the gastropods, corals, brachiopods, and trilobites were advanced forms. It is, therefore, safe to consider this fauna as strictly intermediate between the typical (New York) Onondaga and the typical (New York) Hamilton.

THE STRATIGRAPHIC POSITION OF THE DUNDEE-COLUMBUS.

Whitfield has shown that on the Sciota River and near Dublin, Ohio, the Delaware (Hamilton) and Columbus are separated by a thin bed of black shale with a fauna like that of the Marcellus shale of New York. The species found in this shale were: 1. *Lingula manni* Hall; 2. *L. ligea?* Hall; 3. *Orbiculoidea minuta* Hall; 4. *O. lodiensis* Hall; 5. *Chonetes scitula* Hall; 6. *C. reversa* Whitfield; 7. *Spirifer maia* (Billings); 8. *Leiorhynchus limitaris* Vanuxem; 9. *Aviculopecten? equilatera* (Hall); 10. *Pterinea (Aviculopecten) similis* Whitfield. Of these, Nos. 3, 4, 8 and 9 are typical Marcellus fossils of New York; Nos. 1, 2 and 5 are Hamilton species; No. 7 is an Onondaga form, and the others are new.

Whitfield's conclusion that these shales represent the Western extension of the Marcellus of New York is undoubtedly correct, as is clear from the fauna, as well as from the bituminous character of the sediments. These deposits seem to disappear northward, though the relationship of the Dundee and the overlying Traverse of Southern Michigan is not yet understood. Clarke* has recently shown that the base of the Marcellus of Eastern New York is

*N. Y. State Mus. Bull. 49, p. 115.

stratigraphically lower than that of the same formation in Western New York. At least 50 feet of black "Marcellus" shale overlying the Onondaga in the Schoharie region is represented in Western New York by Upper Onondaga. This is shown by the fact that the Agoniatite limestone, which in the Schoharie region is separated from the Onondaga by the above mentioned 50 feet of black shale, is an integral part of the Upper Onondaga limestone in Western New York. Clarke has interpreted these facts as representing the momentary eastward migration of the Upper Onondaga fauna of Western New York, where limestones continued to form after black shale sedimentation had commenced in the Helderberg region of Eastern New York. In comparing the New York sections with those of the Appalachian region, it appears that this equivalency is much more extensive. Thus at Cumberland, Maryland, the Romney shale, succeeding the Oriskany, probably with a hiatus, represents not only Hamilton and Marcellus of New York, but probably also the greater part, if not the whole of the Onondaga. The Agoniatite limestone has been found by Prosser in this section 170 feet above the base of the black shale. From analogy with the New York sections, we may argue that black shale sedimentation was going on here, while limestones were forming in New York, and that the shales, gradually spread northward and westward over the limestones. Just before they reached Western New York, a reversal of conditions seems to have occurred. the limestone conditions spreading eastward and southward, permitting the Agoniatite fauna to spread over territory which was previously the field of black shale sedimentation.

From the foregoing considerations it would appear that the thin bed of Marcellus shale of Central and Northern Ohio, represents the westward limit of spreading Marcellus conditions. These black muds overlie the Onondaga of Western New York to the extent of 55 feet, followed by the thin Stafford limestone (8 ft.) and about 45 ft. of Cardiff or Upper Marcellus shale. It seems highly probable that these Marcellus shales are represented westward by the limestones of the open sea and pure water, just as the muds of Eastern New York and of Maryland are represented westward by the limestones of the Onondaga. This would make the Columbus-Dundee the stratigraphic equivalent of the Marcellus shales of New York, and would place them stratigraphically above the Onondaga limestone, and since these limestones are thinner than the Onondaga of Western New York, it seems not unreasonable to assume that limestone sedimentation in the Ohio-Michigan region began long after it had set in, in the Western New York

region. This assumption would compel us to regard this region as one of non-deposition during all or most of Onondaga time. It may be that this region was the sea bottom under an ancient ocean current, with water sufficiently shallow to prevent sedimentation under it by its scouring action. Or else what is more likely, this may have been a land area during Onondaga time. In any case, the general absence of reef building corals from these limestones is significant, and argues for a later date for these sediments.*

The study of the Mackinac region has developed the fact that at the beginning of Onondaga time that region was in the state of a semi-desert, surrounded by limestone cliffs which furnished debris to be spread over the valley floor.† This limestone debris was derived from the Monroe formation and is incorporated with the succeeding Mackinac limestone, which, as a result, is brecciated to a high degree. The brecciated phase may be seen on the Island of Mackinaw and on the mainland to the west (Pt. St. Ignace). To a slight extent, it is still visible east of Mackinac City, where, however, the Mackinac limestone is largely made up of the finer sand and mud resulting from the breaking up of the limestone of the cliffs which surrounded the desert area.

The age of the limestone about Mackinac is probably greater than that of the Dundee of Northern Michigan. For this reason, and because the faunas are to a certain extent distinct, it is well to use a distinctive name for this formation. The name Mackinac limestone would seem to apply, and is so used in this report. This limestone appears to be more nearly equivalent to the Onondaga of New York, and it is at its base that the Schoharie fauna of Northern Michigan has been discovered.‡

On the view that the Mackinac limestone (the so-called Dundee of the Mackinac region) is the approximate equivalent of the Onondaga and Schoharie of New York, the succeeding Bell shales of Northern Michigan represent in part the horizon of the Marcellus, but with a different type of sedimentation. It is to this shale series that the Dundee-Columbus of Southern Michigan and Ohio corresponds, at least in part. Whether it began earlier, during the later stages of sedimentation of the Mackinac limestone, or whether the base of the Dundee and that of the Bell shale are approximately synchronous, will probably appear from

*See the discussion of Devonic Coral Reefs in the author's Principles of Stratigraphy—A. E. Seiler & Co., 1913.

†Grabau, A. W. Subaerial erosion cliffs and talus in the Lower Devonic of Michigan. Science, N. S., vol. 25 pp. 295-296. See also Principles of Stratigraphy, chapter XIII.

‡Grabau, A. W. Discovery of the Schoharie fauna in Michigan. G. S. A. Bull., vol. 17, pp. 718, 719: 1907.

further study of the northern faunas. In the latter case, the Dundee is probably also represented in part by the Lower Traverse limestones; and, in any case, it appears as if the Dundee is probably to be regarded as a member of the Traverse Group as developed in Northern Michigan.

Summary of Results. Summarizing the results so far obtained by the study of the fauna of the Dundee limestones of Southern Michigan, we find that both palaeontology and stratigraphy point to an intimate relationship between it and the Traverse (Hamilton), and that it is probably the stratigraphic equivalent of the Lower Traverse. This relationship and that with the Marcellus and Onondaga of New York is brought out by the following diagram.

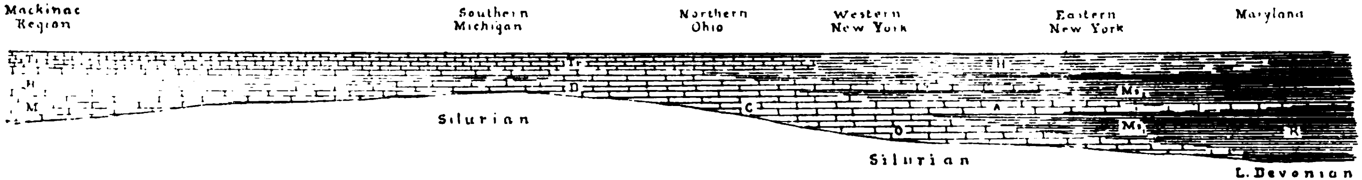

Figure 22. Ideal section from Maryland to Northern Michigan, crossing western New York, Ohio, and Northern Michigan.

A. Agoniatite limestone.
B. Bell shale (Lower Traverse).
C. Columbus limestone of Ohio.
D. Dundee limestone of Southern Michigan.
H. Hamilton of New York.
M. Mackinac limestone of Northern Michigan.
MS_1 Lower Marcellus of Eastern New York.
MS_2 Upper Marcellus of Eastern New York.
O. Onondaga of New York.
R. Romney shale of Maryland.
Tr. Traverse of Michigan—Delaware of Ohio.

SUPPLEMENTARY NOTE.

After the preceding report had been submitted, the admirable bulletin on The Middle Devonian of Ohio, by Clinton R. Stauffer has appeared.* It comprised a historical sketch of the study of the Middle Devonian of Ohio, with a brief review of the corresponding horizons of adjoining districts, followed by a detailed study of the various sections in Ohio with list of the species obtained from the various beds. A chapter, discussing the relationships of the Middle Devonian of Ohio with palaeogeographic maps, and one giving descriptions and illustrations of new or important species completes the work.

This discussion is of the greatest interest and significance in connection with the study of the Dundee, as well as the Traverse fauna, for this is the latest and most detailed information regarding the characters and faunas of the Ohio extension of our Michigan formations, and we are fortunate to have such a timely contribution. Extensive use will be made of it in the discussion of the Traverse faunas as a whole, but, for the present, reference will be made only to the section and faunas of the Columbus limestone of Northern Ohio and their bearing on the problem of the Dundee of southern Michigan.

In northwestern Ohio, where the rocks represent the direct continuation of the Michigan beds, the Columbus limestone is a fossiliferous gray limestone in the upper part, passing downward into a sparingly fossiliferous brown limestone, resembling the lower part of the same formation in central Ohio. The total thickness probably does not exceed 60 feet. The series rest disconformably upon the Lucas dolomite of the Monroe, and is overlain by the limestones and shales of the Traverse formation, there being no marked lithic change from the Columbus to the Traverse, the dividing line being indicated by the introduction of a large number of Hamilton species. There is thus no evidence of Marcellus sedimentation in this section which was beyond the reach of the mud-bearing currents from the east. The Black Shale overlies the Traverse disconformably as everywhere in this region.

In the vicinity of Silica, Ohio, just north of the Michigan line and 2¼ miles southwest of Sylvania, a number of quarries furnish good sections of the Dundee as well as the Upper Monroe beneath it. These were all visited by the writer in company with Prof. Sherzer, and the similarity of this rock to that of Monroe county, Michigan, was noted. The fossiliferous crystalline gray limestone

*Geological Survey of Ohio, 4th Series, Bull. 10, dated Nov., 1909, issued June, 1910.

of this section is 13 feet or more in thickness and underlain by 42 feet of compact brown limestone in marine beds, with a few fossils in the upper part. The rock is especially characterized by the large discs of the stem of an undescribed species of Hexacrinus and from it Stauffer records the following species:

FORAMINIFERA.

1. *Calcisphaera robusta* Williamson.

HYDROCORALLINES.

2. *Stromatopora ponderosa* Nicholson.
3. *Syringostroma densa* Nicholson.

ANTHOZOA.

4. *# *Acervularia davidsoni* E. & H.
5. # *Cyathophyllum rugosum* E. & H.
   (*Acervularia rugosa*) E. & H.
6. *Cladopora frondosa* Nicholson.
7. # *Favosites emmonsi* Rominger.
8. * *F. hemisphericus* (Troost).
9. *F. polymorphus* Goldfuss.
10. *# *Zaphrentis cornicula* E. & H.
11. *Z. gigantea* (?) Rafinesque.
12. * *Zaphrentis* sp.

BRYOZOA.

13. *# *Cystodictya gilberti* (Meek).
14. *Monotrypa tenuis* (Hall).

BRACHIPODA.

15. *Amphigenia elongata* (Vanuxem).
16. *Anthyris vittata indianensis* Stauffer.
17. *# *Antrypa reticularis* (Linn).
18. *# *A. speciosa* Hall.
19. *Camarotoechia billingsi* Hall.
20. *Chonetes arcuatus* Hall.
21. *Chonetes hemisphericus* Hall.
22. *# *Chonetes mucronatus* Hall.
23. * *Chonetes* sp.
24. * *Cryptonella lens* Hall.

25. *# *Cyrtina hamiltonensis* Hall.
26. * *Cyrtina umbonata alpenensis* Hall.
27. * *Eunella lincklaeni* Hall.
28. * *Nucleospira concinna* Hall.
29. # *Orthothetes (Schuchertella) pandora* (Billings).
30. # *Pentamerella arata* (Conrad).
31. *Pholidops patina* Hall and Clarke.
32. *# *Pholidostrophia iowaensis* (Owen).
33. *# *Productella spinulicosta* Hall.
34. * *Rhipidomella cyclas* Hall.
35. *# *R. vanuxemi* Hall.
36. # *Schizophoria propinqua* Hall.
37. *Spirifer acuminatus* (Conrad).
38. # *Sp. gregarius* Clapp.
39. # *S. grieri* (?) Hall.
40. # *Spirifer manni* Hall.
41. *S. segmentum* Hall.
42. *S. varicosus* Hall.
43. * *Spirifer* sp.
44. *# *Stropheodonta demissa* (Conrad).
45. *# *S. hemisphaerica* Hall.
46. # *S. inaequiradiata* Hall.
47. *# *S. perplana* (Conrad).
48. *Strophonella ampla* Hall.

PELECYPODA.

49. * *Actinopteria boydi* (Conrad).
50. * *Aviculopecten* sp.
51. *# *Conocardium cuneus* (Conrad). (*C. trigonale* Hall).
52. *Glyptodesma occidentale* Hall.
53. *Limopteria pauperata* Hall.
54. *Paracyclas elliptica* Hall.
55. *Modiomorpha concentrica* (Conrad).
56. *Pencnka alternata* Hall.
57. * *Pterinea flabellum* (Conrad).
58. *Schizodus* sp.

GASTROPODA.

59. *Callonema lichas* (Hall).
60. # *Euomphalus decewi* Billings.
61. *Isonema (Callonema) humile* Meek.
62. *Loxonema robustum* (?) Hall.

63. # *Murchisonia (Hormotoma) desiderata* Hall.
64. # *Platyceras carinatum* Hall.
65. # *Platyceras dumosum* Conrad.
66. * *Platyceras* sp.
67. *Pleurotomaria arata* Hall.
68. # *Pleurotomaria lucina* Hall.
69. # *Trochonema meekanum* Miller.

CONULARIDA.

70. *Coleolus crenatocinctus* Hall.
71. # *Tentaculites scalariformis* Hall.

CEPHALOPODA.

72. *Gyroceras* sp.
73. *Orthoceras ohioense* Hall.
74. *Orthoceras* sp.

TRILOBITA.

75. *Phacops cristata* Hall.
76. # *Proetus planimarginatus* Meek.
77. *Proetus rowii* (Green).

BLASTIODEA.

78. *Nucleocrinus verneuili* (Troost).

CRINOIDEA.

79. * *Megistocrinus spinulosus* Lyon.

PISCES.

80. *Dipterus eastmani* Stauffer.

Of this series of 80 species, those marked with an asterisk (*) also occur in the Traverse group immediately overlying in northwestern Ohio. Thirty species (marked with #) or 37.5% have been obtained from the Dundee of southern Michigan, where a number of species, not yet recorded from northwestern Ohio, occur. Allowing for the personal element in identification, it probably remains true that 50% of the species identified from northwestern Ohio have not yet been found in Michigan, but will undoubtedly be found. At the same time, about 52 species out of 85 species

identified from Michigan, or 61%, have not been obtained from the Ohio section. Again allowing for the personal element, we may say that 50% of the Dundee species of northern Michigan have not yet been recorded from northwestern Ohio. The total number of species which we may consider identified from the Dundee of southern Michigan and northern Ohio is very near 125. Of these, the largest number of species is found among the brachiopods of which there are over 50 species or about 40% of the total number. Several of those found in the upper beds of the Sibley quarry, classed with the limestone as Dundee, were recorded by Stauffer only from beds referred to the Traverse in the Ohio extension. Among these is the form described in the preceding pages as a larger variety of *S. bidorsalis* Winchell, which Stauffer describes as a new species, *S. lucasensis* Stauffer. This form, in Lucas county, is found in the Traverse and it is not improbable that the upper layers of the Sibley quarry are their equivalent. Whether or not this is the case their ultimate relationship between the lower beds—the true Dundee, and the upper beds—typical Traverse, is undoubted, and there can be no doubt that continuous deposition of calcareous sediments was going on in the southern Michigan area while the black Marcellus muds of eastern New York and Pennsylvania were accumulating. The only question to be determined is, Did the lower or Dundee beds accumulate in the Michigan-Ohio area during the deposition of the post-Onondaga black muds of New York, or was this period synchronous with the pre-Dundee beds of southern Michigan, i.e. during the time when the beds referred to the Traverse in southern Michigan were accumulating? It seems almost certain that the former was the case as indicated by the more advanced character of the Dundee fauna and its comparative dissimilarity to the Onondaga.

In central Ohio, occurs the true Columbus fauna which is much richer in corals than is the Dundee. It seems as if we have here a somewhat earlier fauna than that of the Dundee, a fact further indicated by the Marcellus character of the upper Columbus beds of this region as already noted. The lists given by Stauffer greatly amplify that published by Whitfield, which was used as the basis of discussion in the preceding part of this report. In addition to the species listed by Whitfield the following have been obtained by Stauffer:

HYDROZOA.

1. *Dictyonema leroyensis* Gurley.

ANTHOZOA.

2. *Aulacophyllum convergens* Hall.
3. *Blothrophyllum cinctutum* Davis.
4. *Chonophyllum magnificum* (?) Billings.
5. *Cladopora frondosa* Nicholson. (Traverse in northern).
6. *C. pulchra* Rominger.
7. *C. robusta* Rominger.
8. *C. tela* (?) Davis.
9. *Cyathophyllum multigematume* (?) Davis.
10. *C. validum* Hall.
11. *C. sulcatum* (?) Billings.
12. # *Craspedophyllum archiaci* Billings.
13. *Diphyphyllum bellis* (?) Davis.
14. *Eridophyllum stramineum* Billings.
15. *Favosites goldfussi* d'Obigny.
16. *F. maximus* (Troost).
17. *F. radiciformis* Rominger.
18. *Heliophyllum porcilatum* Hall.
19. *Pleurodictyum problematicum* Goldfuss.
20. *Syringopora pereleyans* Billings.
21. *Zaphrentis spissa* (?) Hall.
22. *Z. ungula* (?) Rominger.

BRYOZOA.

23. *Coscinium striatum* Hall & Simpson.
24. *Fenestella erectipora* (?) Hall.
25. *F. parallela* (?) Hall.
26. *Fistulipora substellata* (?) Hall.
27. *Monotrypa tenuis* (Hall).
28. *Nemataxis fibrosus* Hall.
29. *Polypora celsipora* (Hall).
30. *P. celsipora minina* (?) Hall.
31. *P. flabelliformis* (?) (Hall).
32. *P. robusta* (Hall).
33. *Prismopora triquetra* Hall.
34. *Semicoscinium bi-imbricatum* (Hall).
35. *S. semi-rotundum* (?) (Hall).
36. # *Unitrypa lata* (Hall).
37. *U. tegulata* (Hall).

BRACHIOPODA.

38. *Amphigenia elongata* (Vanuxem).
39. # *Athyris vittata indianaensis* Stauffer.
40. # *Camarospira eucharis* Hall.
41. *Centronella glansfagea* Hall.
42. *Charionella scitula* Hall.
43. *Chonetes hemisphericus* Hall.
44. *Cryptonella lens* Hall.
45. *Cyrtina crassa* Hall.
46. # *Eunella lincklaeni* Hall.
47. *Meristella rostrata* (?) Hall.
48. *Metaplasia disparilis* (Hall).
49. *Pholidops patina* Hall & Clarke.
50. *Rhipidomella cleobis* Hall.
51. *Rhynchonella* (?) *raricosta* Whitfield.
52. *Spirifer divaricatus* Hall.
53. *Spirifer fornacula* Hall.
54. *Strophalosia cf. truncata* (Hall).
55. # *Stropheodonta concava* Hall.
56. # *S. inaequistriata* (Conrad).
57. # *S. parva* (?) Hall.

PALECYPODA.

58. # *Actinopteria boydi* (Conrad).
59. # *Aviculopecten cleon* Hall.
60. *Aviculopecten cf. pecteniformis* (Conrad).
61. # *Aviculopecten princeps* (Conrad).
62. *Clinopistha antiqua* Meek.
63. *Conocardium cuneus attenuatum* (Conrad).
64. *C. cuneus subtrigonale* d'Obigny.
65. *Glossites teretis* (?) Hall.
66. *Glyptodesma occidentale* Hall.
67. *Goniophora cf. hamiltonensis* Hall.
68. *Grammysia arcuata* (Conrad).
69. *Grammysia secunda* (?) Hall.
70. *Grammysia subarcuata* (?) Hall.
71. *Limopteria pauperata* Hall.
72. *Modiomorpha concentrica* (Conrad).
73. *Nucula niotica* Hall & Whitfield.
74. *Panenka alternata* Hall.
75. # *Schizodus appressus* (Conrad).

76. *S. contractus* Hall.
77. *S. tumidus* Hall.
78. *Solemya vestuta* Meek.

GASTROPODA.

79. *Bellerophon acutilira* (?) Hall.
80. *Bellerophon hyalina* Hall.
81. *Bellerophon rotalinea* (?) Hall.
82. *Callonema bellatulum* (Hall).
83. *C. clarki* Nettelroth.
84. *C. imitator* Hall & Whitfield.
85. *C. lichas* (Hall).
86. *Coelidium strebloceras* (?) Clarke.
87. *Cyclonema crenulatum* Meek.
88. *Loxonema gracillium* Whiteaves.
89. *Loxonema pexatum obsoletum* Hall.
90. *L. robustum* Hall.
91. *L. sicula* (?) Hall.
92. *Macrocheilus hebe* (?) (Hall).
93. *M. macrostoma* (Hall).
94. *Hormotoma eversolensis* (Stauffer).
95. *H. intermedia* (Stauffer).
96. *H. leda* Hall.
97. *H. quadricarinata* (Stauffer).
98. *Naticopsis comperta* Hall.
99. *Platyceras blatchleyi* Kindle.
100. *P. cymbium* Hall.
101. *P. erectum* (Hall).
102. *P. rarispinosum* Hall.
103. *P. rictum* Hall.
104. *P. thetis* Hall.
105. *P. lineatum* Conrad.
106. *P. subglobosa* Stauffer.
107. *Pleurotomaria cancellata* Stauffer.
108. *Pleurotomaria dublinensis* Stauffer.
109. *P. hyphantes* Meek.
110. *P. insolita* Hall.
111. *P. plena* Hall.
112. *P. procteri* Nettelroth.
113. # *P. regulata* (?) Hall.
114. *P. sciotoensis* Stauffer.
115. *Porcillia sciota* Hall & Whitfield.

116. *Pseudophorus antiquus* Meek.
117. *Straparollus corrugatus* Stauffer.
118. *Strophostylus varians* Hall.

CONULARIDA.

119. *Coleolus crenatocinctus* Hall.

CEPHALOPODA.

120. *Agoniatites discoideus* (Hall).
121. *Anarcestes cf. lateceptatus* Beyrich.
122. *Cyrtoceras cretaceum* Whitfield.
123. *Cyrtoceras metula* (?) Hall.
124. *Cyrtoceratites ohioensis* Meek.
125. *Gomphoceras arcuatum* Hall.
126. *G. gomphus* Hall.
127. *G. impar* Hall.
128. *G. mitra* Hall.
129. *G. plenum* Beecher.
130. *Gyroceras cyclops* Hall.
131. *Orthoceras dagon* Hall.
132. *Orthoceras molestum* Hall.
133. *O. sirpus* Hall.
134. *O. thoas* Hall.
135. *O. winchelli* Meek & Worthen.
136. *Tornoceras ohioense* Whitfield.

TRILOBITA.

137. *Chasmops anchiops* Green.
138. *Coronura diurus* (Green).
139. *Odontocephalus aegeria* Hall.
140. *O. bifidus* Hall.
141. *Phacops cristata* Hall.
142. # *Proetus rowii* (Green).

BLASTOIDEA.

143. *Codaster pyramidatus* Shumard.
144. *Nucleocrinus verneuili* (Troost).

CRINOIDEA.

145. *Dolatocrinus caelatus* (?) Miller & Gurley.
146. # *D. glyptus* (Hall).

147. *D. greenei* (?) Miller & Gurley.
148. *D. lacus* Lyon.
149. # *D. livatus* (Hall).
150. *D. major* Wachsmuth & Springer.
151. *D. ornatus* Meek.
152. *Megistocrinus depressus* (Hall).
153. *M. rugosus* Lyon & Casseday.
154. *M. spinulosus* Lyon.

PISCES.

155. # *Acanthaspis armata* Newberry.
156. # *Acantholepis fragilis* Newb.
157. *Cladodus prototypus* Eastman.
158. *Cyrtacanthus dentatus* Newberry.
159. *Dinichthys precursor* Newberry.
160. # *Machaeracanthus major* Newberry.
161. # *M. peracutus* Newberry.
162. # *M. sulcatus* Newberry.
163. # *Macropetalichthys rapheidolabis* Norwood & Owen.
164. # *Onychodus sigmoides* Newberry.
165. # *Palaeomylus crassus* (Newberry).
166. # *P. frangens* (Newberry).
167. *Psammodus antiquus* Newberry.
168. # *Rhynchodus secans* Newberry.
169. *Thelodus* sp.

A study of this table will show that, in spite of the abundance of Onondaga species, many typical Hamilton forms occur. Those marked with a # also occur in the Hamilton (Delaware and Prout) of Ohio. One of the striking features of this fauna is the abundance of the corals and hydrocorallines which, as pointed out by Stauffer, make extensive reefs in central and southern Ohio. These reefs are probably of the same age as those of the Falls of the Ohio region, and both may be contemporaneous with the reefs of western New York. The higher beds of the Columbus and the Jeffersonville limestones as well, probably represent in part, at least, the Marcellus of western New York and this is most certainly true of the Dundee of northern Michigan and northwestern Ohio. Here the corals are absent or but slightly developed, and this seems to be due to the fact that the coral horizon here is overlapped by the higher beds of the series, which here come to rest directly upon the Silurian. It is these higher beds, the typi-

cal Dundee, which are regarded as the representative of the Marcellus of western New York.

It thus appears that the further knowledge gained by the detailed study of the Columbus fauna, as presented in Stauffer's admirable bulletin, bears out the conclusions reached by the study of the Dundee fauna of southern Michigan. Stauffer suggests that the difference of the two faunas is in part accounted for by the occurrence of a land barrier. On the interpretation above given, this barrier becomes unnecessary, for the Michigan-northern Ohio area was land during the growth of the coral reefs in southern Ohio, western New York and the Falls of the Ohio region, as well as the northern Michigan and Canadian regions, and only became submerged by the slow northward and southward transgressions of the sea during the succeeding period, and the overlapping of the later over the earlier strata. A few further facts given by Stauffer agree well with this interpretation. Thus *Spirifer gregarius* becomes an abundant fossil in the middle part of the Columbus limestone of central Ohio, but, in the northern Ohio and southern Michigan areas, its place is at the base of the formation. *Meristella nasuta* is another species holding a similar relationship. This does not in any way negative Stauffer's conclusion that the coral fauna of the Onondaga came from the north. That conclusion may be well founded, as shown by the distribution of the corals. But the absence of the coral elements in the southern Michigan and northern Ohio areas is to be regarded as due to nondeposition there, rather than distinctness of waters, and to subsequent overlap of the higher beds of this series.

The full discussion of this problem is reserved for the monograph on the Middle Devonian Faunas of Michigan now in preparation.

Columbia University,

New York City.

June, 1910.

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